

AVIATION

The Oldest American Aeronautical Magazine



SPECIAL FEATURES

Sales Factors IN THE CABIN PLANE MARKET

Lumber Built AIRPLANE HANGARS

AERONAUTICAL *Engineering* SECTION

An

Any airplane engine is an alloy product in no better than the degree of accuracy with which each part is made and used.

This is particularly true of the V-8 moving parts.

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Produced by Quality*



The Heald Machine Co., Worcester, Mass., U.S.A.

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Gypsy Moths hold a number of international records, and everywhere they have proved themselves dependable light planes.

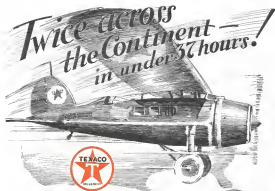
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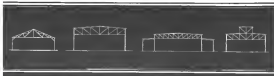
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PUT the Whitley Avian through its paces. Not with the conscious effort of a "show-off," but with the casual ease of a born aviatorist this famous light plane responds to every wish and whim of its pilot.

From the moment you give it the gun, until it flutters into a gentle three-point landing, propeller still, stick dead, the Avian gives a flying performance that is a happy combination of stability, ease-of-handling, speed, durability and safety.

It is the creature of genius. It must be. For more than five years ago, to write in the sky-lanes of the world a glorious history of achievement, many designers have attempted to duplicate the Avian. They have copied it line for line, angle for angle. Still, the Avian remains the crown of the experienced pilot—as a ship in which to train the beginner, as a ship to fly for sport.

1. You can't take it off the front porch. But no light plane is quicker to lift its nose into the air and leave the ground behind. By the same token, you can land the Avian in any pasture or tennis court.

And from take-off to landing the Avian will give you the most comfortable, satisfying flight.

Among the features that make the Avian the most versatile light plane for day-as-and day-out flying—whether training or testing—are:

LARGELY. With it the factor of safety the Avian is one of the most popular planes for sport and training. Allwoodhouse permits construction at a total loaded weight of 1450 pounds, normal flying at a weight of 1600 pounds. The Avian, pilot, passenger and 50 pounds of baggage weigh 1450 pounds.

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to accommodate two full-sized suitcases, tools, spare tire, etc.

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RECORDS & IDEAS. First solo flight England to Australia. . . . Fastest time England to Australia. . . . Longest flight ever made in a light plane. . . . Longest solo flight ever made. . . . Fastest time England to India. . . . First non-stop flight, London to Rome.

Write for information. If you are interested in the Whitley Avian as a purchaser or if you plan the conduct of a training school, write us. We will gladly forward complete and detailed information concerning this light training and sport plane. In your 5 days' journey of P. O. B. Bridgeport, Conn., Whitley Mfg. Company, Dept. G-6, General Office and Plant, Bridgeport, Conn.



IN ENGLAND



IN AMERICA

THE OUTSTANDING SPORT AND

TRAINING PLANE OF THE WORLD

★ PROVING AGAIN ★



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BEFORE the onslaught of the swift Lockheed Air Express, piloted again by Captain Frank Hawks, two transcontinental records fell! From New York to Los Angeles, and from Los Angeles back to New York in little more than 36 hours flying time! A new record from East to West; a new record from West to East, and both made with Lockheed! It is expected of Lockheed to set new records, for every Lockheed is a champion. Its fighting heart, its tremendous strength and its speed increasing lines make streaking speeds possible with utmost safety! And now, when a new transcontinental record is set, Lockheed will set it, for more than ever before is demonstrated...It Takes a LOCKHEED to Beat a Lockheed!

Lockheed Aircraft Company

Los Angeles, U. S. A.

Lockheed Air Express, Approved Type Certificate No. 103

LOCKHEED

Lockheed Aircraft Corp., General Sales Representatives, Detroit, Mich.

CLANK TON for watching AVIATION

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Passengers Must Be Flown in Safety



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Phillips Aviation Gasoline, now in its third successful year of manufacture, is characterized by—easy starting, more engine revolutions per minute, more power of operation, more available because of BETTER DISTRIBUTION TO ALL CYLINDERS.

Phillips Aviation Gasoline is used by air mail contractors, and by a steadily increasing number of passenger transport lines.

Available at many airports.

Phillips

AVIATION

PHILLIPS PETROLEUM CO.
BARTLESVILLE, OKLAHOMACopyright 1937
Phillips Petroleum Co.

NATURAL GASOLINE FOR CONTROLLED VOLATILITY

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Allison Engineering Co.
American-Crown Eng. Co.
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Lulland Aircraft Engines Co.
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McClelland Manufacturing Co.
Nashua Aero Engine Corp.
Sury Department
Pitts & Whitney Aircraft
O. E. Siskaly Corp.
Worthington-Air Corp.
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Continental Motors Corp.
Curtis-Camion Inc. & Co.
Dodge Bros. Corp.
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H. H. Franklin Mfg. Co.
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Marmon Motor Car Co.
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Mastor Truck Co.
Minneapolis Truck & Mfg. Co.
Mississippi Thresher Machine Co.
Snyder Motor Truck
Solomon, Inc.
Selden Truck Co.
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Wheeler Motor Co.

135 manufacturers use Stromberg carburetors as standard equipment. This impressive list, shown here, contains representative firms in every line of industry where motors are used.

These firms KNOW that Stromberg superior performance is the result of the highest type of carburetion engineering, the finest workmanship, the best materials procurable.

They recognize real merit and are willing to pay for it.

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Operates automatic chemical plane on 100 lbs. gas with single pump action.

Cardinal Points of the PHY-LAX Fire Extinguisher

1. Construction includes the latest mechanical workmanship.
2. Ready to operate in each position and does not require manual effort to operate.
3. Working (including safety) only 100 lbs. pressure is needed to get maximum effect as soon as the chemical is released.
4. Positive positive fire protection (the perfect flameless, reliable and rugged).
5. Operating advantage for pilot in emergency.
6. Operates automatically, requires no manual effort when needed.
7. Portable, convenient operation. Not affected by shock or vibration.
8. Fire extinguishing chemical is completely safe for property.
9. Automatic break down in airplane engine of each motor, including engine and oil pump.
10. Has most every test and proved for positive operation under all conditions.

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Leave This Invisible Passenger Behind...

No fire board sides the plane equipped with PHY-LAX—the seating fire extinguishing system which instantly smother the first flicking flame.

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PHY-LAX provides a series of sprinkler heads, strategically placed about the motor and plane, which automatically release a flow of smothering chemical the moment fire breaks out.

This chemical is supplied

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There is a PHY-LAX installation for every type of motor and plane—at the uniform, moderate price of \$70 complete. Indeed, the lowest cost insurance for the highest form of absolute fire protection. Full particulars will be mailed on request.

AERO SUPPLY COMPANY
COLLEGE POINT, LONG ISLAND, NEW YORK
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THE AUTOMATIC FIRE EXTINGUISHER FOR AIRPLANES

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Lowell Barlow, chief pilot of Eastern Steam Turbine Corporation, flying over Springfield, Mass., in his Boeing powered "Pawnee" plane.

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ELEVEN planes regularly stationed at the Springfield, Mass., Airport use Socony products. The fact that Socony Aviation Gasoline has been the official gasoline ever since the port was opened a year ago speaks for its quality.

Socony Aviation Gasoline and Aircraft Oils are

readily available at airports throughout New York and New England. Uniform in quality, they are designed for flying under the most exacting conditions.

SOCONY

MADE IN U.S.A.

AVIATION GASOLINE · AIRCRAFT OILS

STANDARD OIL COMPANY OF NEW YORK

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Safe Haven

Knowing pilots spot the sign and pick out the airport where Naturaline is sold. It is assurance of the best accommodation and the best fuel.

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Many of the outstanding mail lines, transport companies and airport operators use Naturaline exclusively because of the following advantages: It starts quicker. Fuel consumption is less. Its power output is greater. The improved motor performance is marked. It is lighter in weight. It reduces the cost of motor over-haul.

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OF AMERICA**
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A Big Plane in STABILITY and FLYING Characteristics

Davis has combined in a compact, economical, two-place monoplane the inherent stability, performance and flying characteristics previously found only in larger and heavier planes.

It is a fact that the unusual and exclusive wing design of the Davis V-3 Monoplane achieves a degree of inherent stability—even in rough weather—far beyond previous light plane experience.

It is a *stable* plane in every detail—so steadily engineered, and so sturdily constructed that operating and maintenance costs are reduced to the minimum.

Read the performance data summarized below. Then you will understand (as well as anyone can tell) they have actually taken the stick) why the Davis V-3 Monoplane is an ideal plane for student training, and for the man who wants a plane for personal use. Write for complete information.

Many new services are still open. Responsible dealers are wanted to serve for complete details of the Davis Franchise.

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Baltimore, Indiana



\$2965
Flies as if fold
Complete
with 16-100 60 H.P.
Radial Engine

DAVIS V-3 MONOPLANE

A TWO-PLACE HIGH-WING MONOPLANE—THE AMERICAN MOTIV

THANK YOU for reading AVIATION

PERFORMANCE (Actual)

Service Ceiling	10,000 feet
High Speed	115 M.P.H.
Landing Speed	55 M.P.H.
Cruising Speed	100 M.P.H.
Climb	700 ft. per minute
Fuel Consumption Cruising Speed	65 gallons per hour
Cruising Range	200-400 miles



The Oldest American Aeronautical Magazine

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Number 1-1

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They are selected because of their:
**Dependability—Simplicity
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The majority of modern American Airplane engines are equipped with Scintilla Aircraft Magneto.



Scintilla Aircraft Magneto can be obtained for engine of from one to eight cylinders.

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Contractors to the U.S. Army and Navy

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Sixteen thousand hours of "HORNET" power



THE international fame of the Pratt & Whitney "Hornet" engine rests upon millions of miles of dependable living power.

To illustrate: One transport operator . . . flying thousands of miles on schedule, day and night, with passengers, mail, and express . . . makes this report of 44 "Hornets":

In 16,757 hours of total operation to date, the 44 "Hornets" have flown a total of 1,709,200 miles. The average number of flying hours per engine has been 3800. The average number of miles per engine is 38,205. The average hours for the six engines longest in service is 376. The average number of miles flown by these six engines to date is 59,332.

This record should be significant to those seeking the speed, comfort, safety that come from "power in reserve".

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HARTFORD, CONNECTICUT
Division of United Aircraft & Transport Corporation

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Wasp & Hornet Engines

WRITE FOR CATALOGUE AVIATION



THE OLDEST AMERICAN AERONAUTICAL MAGAZINE

A National Aeronautics Association Publication ESTABLISHED 1918

FORWARD P. WALKER, Editor

Number 111 • July 26, 1929 • 4th Year



Air Regulation

THE AIR COMMERCE ACT of 1926 was the first definite step in the Federal regulation of aircraft and aircraft operation in these United States, and although there are those who have wished in the past that the industry is being stifled with "over-regulation," had it not been for that Act we would today undoubtedly be in an extremely hodge-podge state of affairs, and faced with peril of stagnation in the industry.

It is quite possible that there are existing air regulations that annoy the major portion of the industry, and which were primarily enacted to be aimed at the wrong end. No doubt there are provisions that could with advantage be modified or stricken from the books. Yet, it should be realized that there was no precedent for aeronautical law and regulation, and that it has been necessary to proceed by trial.

Taking all in all, the Regulation Division of the Transportation Branch has performed an exceptionally fine job in the time allowed. That job is not finished, nor will it ever be finished. Presently each new law brings need of regulation for some new or entirely changed phase of aeronautics. As an example the recent reorganization of trans-continental air-mail service has brought up the problem of regulation covering the operation of other aircraft over the route of the coast-to-coast service. Where is there a precedent upon which regulation can be based to determine air space rights for the airline, whether to restrict mail loadings? Should the airline or the individual mail operator confer with the landing fee figure for planes landing on the airline's airports, particularly if they happen to be based from or destined by the local municipality?

There are indeed a hundred and one regulations that would have to be enacted and amended before all the rough edges could be rubbed away. We shall continue to hear complaints after complaints, many of which will be completely justified. If ground for them all could be removed we would be eternally grateful to the "aeronauts," but unfortunately, in air regulation as in so many other things, the millennium is still far away.

While awaiting it, our best resource is to give the regulating bodies the complete cooperation that they rightfully deserve. We reserve the right to disagree with them. We shall criticize from time to time, and we believe that they welcome criticism based on a desire to help. But instead of selecting which regulations we shall follow and which we shall not, let us cooperate loyally in carrying out the entire lot until better substitutes are brought to light. Too much regulation may indeed stifle progress, and too little regulation may bring about an even more disastrous result, but haphazard compliance with regulations may be worse than no regulation at all.

//

Mendell and Reinhart

WE HAVE previously expressed the opinion that the technical profit from duration flights with refueling, and from various other attempts at record breaking, would be much increased if the holders of planes and engines would conduct them themselves. We have declared the view that the aircraft industry has little to gain from a wave of enthusiasm for refueling and an indefinite multiplication of such flights.

We have no desire to modify those expressions, but they do not in the least detract from our admiration for the really remarkable performance of the Anglin and her two pilots. It would be impossible to let that pass without comment.

The flight sets up one of those figures which serve as landmarks in the history of record-making. Like the first man to fly at three hundred miles an hour and the first one to reach (many years ago) an altitude of ten thousand feet, the team which first traversed in the air for ten unbroken days and nights is assured of lasting fame.

The engine men too conferred the exaltation justified by the past record of the type. Even 246 hours of flying did not develop the full limits of its capacity. Its performance is a dramatic evidence of the progress

that has been used since, only a dozen years ago. Fifty hours of intermittent running between overland runs at that could be expected. It is a tribute to the courage, persistence, and far-sighted vision of the engine designers and builders and the officers of the naval and military services who trained, not long after the war, that powerplant durability was not actually to be increased by short and occasional stops but was to be detailed and quadrupled without delay.

The airplane did in part, and when it finally gave way it was only the abnormal conditions of its taking that were responsible. It is the case's own share in the record, however, that is most astounding, for we have learned to trust on great things from engines and planes. To spend 286 consecutive hours behind a running engine, half of it at the controls, the time of duty repeatedly broken by the anxious business of refueling and taking on supplies—this constitutes a real test of human endurance. As usual the human organism showed itself possessed of unanticipated resources.

Nothing is further from our minds than to discourage record-breaking. We thoroughly believe in records as an index of progress and as trade publicity. We do, however, suggest that any group planning to break this one should devote themselves to the perfection in detail, with much preliminary practice, of an improved refueling technique, and that they should start only under conditions justifying a reasonable expectation of being able to remain aloft for at least two weeks.

//

"First Stop San Francisco."

PASSENGERS upon air lines are not eager to participate in breaking records. The untold details of the process by which they reach their destination matter little to them. They want to travel safely, quickly, economically, and comfortably, and none of them want breaking records.

These elements are best combined by breaking the journey, where the course of the route flows possible, into stages of from two to four hundred, or certainly not more than five hundred, miles in length. Upon this point theory and practical experience are fully agreed. Beyond that length of non-stop run, the sacrifice of pay load in favor of fuel use into economy so badly that the saving of time cannot compensate.

The idea of the non-stop flight meets a serious objection. There is something romantic about the notion of carrying ordinary passengers from the Atlantic to the Pacific coast, or from North to South America without any halt. But realistic appeal is a variable dimension for the transportation enterprise. Economy and efficiency are much to be preferred to romanticism. There are some areas in which, right located or a thousand miles apart, be covered without stop because of impossible local conditions. There are long over-water

routes without possible landing places upon which it is desirable to provide service. In the vast majority of cases, however, it is perfectly feasible to break the journey at intervals of three or four hours. To do so is more economical. It is actually pleasanter for the passengers, who have a chance to get out and move about. It lengthens the total time of the journey by a few minutes at most. To fail to take advantage of such opportunities for intermediate landings is sheer waste.

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An Air Mail Anniversary

JUST ABOUT three years ago this date, the last of the original group of private air mail contractors were getting under way—a very advanced experiment in the field of air transportation. It was such an experimental affair, in spite of facts and figures derived from Post Office Department operation of the transcontinental trunk line, that the predominant emotion in each new line was doubtless was a very anxious feeling.

During some of the last periods which followed, this faith was put to severe tests. Now that these lines are paying their way or are about ready to jump over to the blue side of the ledger from the red side, and inasmuch as many other operators subsequently have joined the ranks of the original group, it is obvious that faith has been triumphant.

This is not to say that launching these so-called feeder lines was a leap in the dark, a bit of uninspired blind flying, so to speak. Had this been so a "crash" would have been the logical outcome. In most cases confidence in the air mail contract system was buttressed by experience in military or independent flying and the procedure to be derived from operations of the old transcontinental.

And so this may be added one of the deepest secrets for the stuporous record of the three years—the willingness on the part of the operators to learn well the lessons taught by the days and nights of feeder line development, which admitted sponsors often felt raring chafed at as hesitations. Carrying the mail on schedule over airways in various stages of perfection and in difficult weather, produced innumerable new problems and the solution called for considerable adaptation.

It is all part of the absorbing history of air mail, how types of aircraft have been evolved to perform the specific job assigned, how night flying and operation through severe headwinds of unfavorable weather have been solved, how radio communications and direction apparatus have been brought into use, and how the public has gradually been "sold" the idea of the service.

Not the least of the difficulties was the last. It constituted a new departure for airlines, and the degree to which it has been conquered is one of the most important factors contributing to the present status of the line. In fact, public patronage is essential, and the

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groundwork in that direction became as important as the operations in the air. In convincing the public that it should use the air mail, the companies achieved an invaluable national by-product, which is being degraded as an "accident-prone."

As the first three years are being rounded out we see the original twelve contract mail routes operating in 1935 extended to twenty-five. From a daily mileage of about 34,000 mi. daily, the greater part being flown at night. So successful has the private contract system been that even the transcontinental run has been turned over to civilian companies, and its schedule has been doubled.

The story, of course, is told in its early chapters. Standing on their newly acquired foundation of air mail experience, most of the companies are planning for, or already are developing, air passenger service—the ultimate goal of air transport. The "experiment" has become an indispensable element in the economic life of the country, and it sweeps around into the fourth year of its existence still animated by faith, but faith now stronger and much more widely shared.

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Steel

THERE ARE national faiths and fancies in aircraft design. The British government for years could see no virtue in welded steel fuselages. One country rejects the idea of the cantilever monoplane, while another will have nothing else. One is quick to adopt the air-cooled engine, another rejects the innovation in the last hour.

In the United States many manufacturers still cling to wooden wing structures. Others, as yet, have not reached up to making up in enthusiasm for their choice what they may lack in volume, have turned wholeheartedly to duralumin.

A very small group indeed have experimented with the idea of welding up spars of alloy steel. Not a single one has made across that of a form of construction that has become almost universal in Great Britain in the last few years, and that is being slowly described by Mr. W. H. Stevens in a series of articles of which the second appears in the current *Aeronautical Engineering* Section—the assembly of spars out of thin strips of steel of very high strength.

There is no evidence, from a comparison of the weights

and performance of British plants with those of other manufacturers, that steel strip possesses any general inherent advantage over the best of the alternative materials of spar construction. There is, however, every reason to believe that for certain types of design and certain wing sections the steel strip can prove itself superior to all its rivals, as for other particular cases it is definitely inferior. Its possibilities should be explored in America. It has made a good enough record in Europe as made it undesirable that we reserve to depend solely on second-hand evidence regarding its capacities.

The value of a constructional material cannot be judged solely in terms of weight for a given strength. Theory tells us incomplete story. The special weakness of steel as a spar material is its extreme susceptibility to local damage. A tiny dent may be responsible for secondary failure at far below the intended strength. Another handicap under which it works is the relative, and often extreme, complexity of fitting design.

There are counterbalancing practical advantages. Spars perfectly constant in form throughout their length, assembled with rivets placed in straight lines on a constant spacing, are ideally adapted for efficient production in really large quantities. Whereas welding inevitably requires the skill and judgment of a trained operator, the assembly of riveted spars can be made virtually automatic, as the crating of the spars in the steel-shed airplane now building near Detroit already has been. The workman has only to keep the material feeding truly into the machine.

The introduction of rust-proof steels heightens the interest of steel wing construction. Resistance to corrosion is a key point in the choice of metals for aircraft service. Twenty years ago "mildsteel" steel was hardly even dreamed of. It has now gained no reputation a place, thanks to the researches of Sir Robert Hadfield and the Krupp firm and others here and abroad, that it will fill a large part to the largest building now under construction in New York. Not yet employed in regular aircraft service, experiments on its fabrication

have been carried to the point of making it quite practicable for spar work on which there is no welding to be done.

The American aircraft industry, taken as a whole, cannot afford to overlook any methods or materials which have been so thoroughly established as to encourage their widespread use by competent construction. To turn to steel strip spars at the expense of abandoning present practices would be worse than foolish. It is a much less serious error, but still it is unwise to neglect their possibilities entirely.

BEGINNING with this issue, the editorial text page of *AVIATION* and the advertising pages will begin at 2 in each issue, while the numbers of the text page will pick up where the text ended in the preceding issue. Page 162 was the last page of *AVIATION* in the July 15th issue and the first page of this issue is therefore 163.

Those readers who had their copies of *AVIATION* will welcome this change as it will enable them to find conspicuously only the editorial text pages of the magazine and will afford an unbroken sequence of page numbers throughout an entire volume.

Sales Factors IN THE CABIN PLANE MARKET



By SAM BREDER

Sales Manager Lockheed Aircraft Company

FOLLOWING the recent popular wave of enthusiasm for flying, aircraft manufacturers have performed wonders in placing new plane designs on a quantity production basis in an attempt to meet the demand. The Lockheed factory, for instance, built only three planes during 1927, yet was able to build and deliver 50 planes during 1928, and according to present production schedules will turn out at least 200 planes during 1929. Similar production records have been established by a number of other companies to give this country a total production for 1928 of about \$25,000,000 worth of commercial aircraft.

Now with all the established factories stepping up production, and with many new factories preparing to build planes in quantity, the 1928 production figure can be doubled during 1929, provided that there is a market for this number of aircraft. The big problem now worrying aerospace engineers are these: Has aircraft production outstripped the present capacity of the market? Have we already reached a temporary saturation point?

The above questions are rather broad when we consider the many types of aircraft now manufactured, and the fact that some planes now being built may have a very restricted market which is now exhausted. Also with the rapid progress in design, new types may destroy the market for many craft now popular. While there is probably a slackening in the demand for some types of aircraft at the present time, we think, here at the Lockheed plant, that the new-market market for certain specialized types of planes has barely been scratched.

From the time that this enthusiasm for flying started in 1927, up to now, planes have been bought, not sold, and anything which would fly was considered a marketable airplane. With present production schedules, and with the public rapidly becoming educated as to what constitutes a good airplane, I believe that it will be necessary from now on to sell airplanes, and what is of greater importance, to build airplanes to sell. That is to say, planes must be designed with a certain type of purchaser

in mind and must be built to meet the anticipated requirements of that purchaser in every detail. After all, it is an economic waste to sell a new something, by clever salesmanship, that will not satisfy him. On the other hand, if a product is fundamentally right it is only necessary to acquaint the prospect with its abilities and he will not have anything else.

Every manufactured article has a certain definite market and a certain limited number of important sales points. Therefore, every manufacturer must decide to outline his market, must establish a definite attitude toward the potential buyers of his product and then must build and sell his merchandise so as to fit the idea-type of his defined market.

In the past there has been a rather disorderly condition in the aerospace industry regarding the manufacturer's attitude toward his market. Many manufacturers



View of the cabin interior of a Lockheed "Boat-tail" biplane looking forward from rear.



The First "Boat-tail" biplane, named "Boat-tail", built in 1927, is shown here.

have been content to let people buy planes without making any real effort to build up a sales and service organization for the future. Other manufacturers have sacrificed present sales and production while they have represented and sought to develop planes for the future market. Here in the Lockheed factory we are sure that we have something of great value to the present market and have been every effort toward developing an organization that could specialize the construction of our planes to meet every possible requirement of the purchaser. At the same time a country-wide distribution organization of the highest and most permanent character has been built up in order to insure prompt sales service and also continued service on planes in use. Along with this effort to serve the present buyer we have been able to introduce many improvements in design and construction which



Another view of the cabin of a Lockheed "Boat-tail" showing the portable typewriter and other utility equipment.

The light open plane, or sport type, the single engine cabin plane, which has many sub-classifications, and the multi-engine planes, which are essentially the trucks and passenger buses of the air. The Lockheed company builds single engine cabin planes of from five to seven passenger capacity because we believe that this type of plane most nearly meets the requirements of the largest present market, and in point of numbers will eventually be the most popular of all aircraft. We believe that there is an almost unlimited market for our type of plane at the present time among the thousands of business executives and larger commercial organizations of the world and with the airlines which are now establishing many short feeder routes requiring fast, efficient, and planes, with which to carry traffic to the main lines. In this connection, it is essential that planes for feeder lines should be better than the large transport planes in order that proper connections may be assured in spite of adverse weather conditions. By placing reliable single engine cabin planes in the service of the leading business men of the country we will win thousands of converts to air transport whose money and enthusiasm will greatly accelerate the development of all kinds of flying.

Regardless of the type of plane built or the demand for it, there are vital reasons why we should merchandise our planes in all sales products are merchandised, as a direct business basis. In merchandising of any sort there are usually about five factors which a sales manager must consider:

- 1 Who are the logical purchasers?
- 2 Who are the men controlling these purchases?
- 3 What is the probable quantity which can be sold this year, next year, and the year after?
- 4 What are the channels through which advertising and publicity should flow?

5 What kind of advertising copy should be developed?

New it is just as possible to determine these factors for airplanes as it is for electric refrigerators, radios, or automobiles, although it may be a bit more difficult because of the mobility with which the aircraft industry is developing.

As we have outlined the factors in connection with Lockheed planes they are something like this:

- The logical purchasers are business executives who place a premium upon time and whose personal attendance at widely separated centers of activity is a real must. Industrial organizations who need the fastest possible transportation of men, money, or materials, and airlines needing planes of great speed and reliability, are capable of making faster loans pay a profit.
- The purchases of planes of Lockheed type are consequently controlled by the industrial executives most directly interested in their operation.
- We know that the quantity sold this year by an aircraft exceed one production of 200 planes, but before that there is an immediate market for several thousand planes of this type among the leading business men of the country. Most such men are now rapidly rising in the air and with turbine fuel are undergoing great development, we believe that there should be a market in this country alone for at least 25,000 single engine planes of the Lockheed type. After 1950 it is a little difficult to predict with intelligence because the major factors upon which the rapid development of flying depends, but of adequate flight routes have been developed, available facilities provided and suitable traffic regulations developed, so can actually create a market for at least 50,000 single engine planes yearly.

- On advertising and publicity we have two widely separate factors to consider in Lockheed airplanes. Because of their speed and safety they have great popular appeal, and the Lockheed company has understood the widespread publicity which has been a result of the many new records set with Lockheed planes. On advertising, however, the possible purchasers constitute a certain limited field of business men and Lockheed has restricted its advertising to the trade magazines which reach airline executives, and to the business press, and society magazines which reach the wealthy business men and sportsmen.

- Advertising copy for Lockheed sales has always sought to emphasize the most important factor in connection with Lockheed's record. *Speed* along with *speed* we seek to play up the colorful beauty of line and finish and the luxurious interior of the plane. Then we tell the prospective buyer that a Lockheed plane will save his time place to place faster than any other means of transportation, will do it with greater comfort than any other vehicle can offer, and that the plane will be a thing of beauty and a possession of which he can always be proud.

With these few factors determined it is possible to

act with decision in the construction and sale of our product. Following the idea that we must build planes to sell, we have always sought first for superior speed, without sacrificing other factors. Speed is the vital thing which all aircraft have for sale beyond anything offered by any other vehicle. Next to speed we consider that speed of the plane for certain definite requirements is most important, and for the reason Lockheed planes have been adapted to either passenger or cargo loads, for the use of airline passengers or private executives desiring the best word in luxury, convenience, and speed; and for operation from land, water, or air.

Taking all these points into consideration we rank them in what we feel to be the order of importance to a sale, something like that: (1) Speed, (2) speed of the plane to the purchaser, (3) luxury, (4) comfort, (5) utility, (6) serviceability, and (7) safety.

Taking these points in order, we believe that speed is the most important because the aircraft market is so highly competitive. Planes are competing against airline transportation on the basis of speed, airlines are competing against each other on the basis of time saved over a given route, and planes are being sold largely on their ability to get pay loads delivered faster than competing planes. The possibility which Lockheed planes have enjoyed from the beginning is because, without sacrificing other factors, they provide superior speed.

We think that speed of the plane to the purchaser is the next biggest factor in the market, and it, in many ways, of more importance than speed. In order to provide a place for every type of service within the market served by Lockheed we have developed three different models. First, the standard "Vega" model for straight passenger carrying at the side of charter parties and local lines where no mail or express is carried, then the "Air Express" for mail lines and feeder lines carrying variable loads of freight and passengers; and finally, the "Excursion," which is built for the private transportation of business men who need the utmost speed and at the same time wish to have comfort and the opportunity to make useful use of leisure.

EACH OF THESE three models has been adapted by Lockheed engineers for operation from land, water, or air, thus providing for the use of Lockheed planes under almost any conceivable condition of weather or geography which poses a flight at all.

The varied uses to which Lockheed's are now being put witnesses to the industry the desirability of this sort of specialization. Mailbox Air Lines, Universal Air Lines, Steam Motor Air Lines, Northern Air Lines, Continental Airways, Ltd., Southwest Fast Air Express, Nevada Air Lines, Washington-Alaska Airways, Texas Air Transport, and United States Air Transport have all placed Lockheed planes in passenger or mail transport service, emphasizing the importance of building planes suited to the needs of each user. Commercial Airways, Ltd., operating between Edinburgh and Port Beaulieu, Canada, has been supplied with planes equipped with wheels, floats, and skis, and these planes are operated from snow, ice, water, or land, according to the varying conditions. The Washington-Alaska Airways have converted their operations between Seattle and Juneau, and have ordered six "Wing" Vegas equipped with pontoons, to fly a 1,000 mi. route over the inland routes of British Columbia and southern Alaska. Although a Lockheed plane in pontoons recently made this

flight non-stop in snow and a half hour, the scheduled time for the trip, with stops, will be 30 hr.

As an indication of the extent to which specialization of aircraft may be carried, the Lockheed Excursion is equipped with a typewriter, writing desk, stationary file, phone to pilot's compartment, bed length couch, and lavatory. That such a plane will find instant favor with business men is indicated in purchases made by the B. F. Goodrich Co., Maryland Oil Co., and Western Gilm MacIsaac.

Beauty is rapidly becoming a dominant factor in aircraft selling, as evidenced by the recent trend toward brighter and more harmonious colors, and cleaner exteriors. Particularly for the lines of the Lockheed planes are extremely beautiful, and this appearance is enhanced by finishing the various planes in an outstanding manner desired by the purchaser. An outboard paint manufacturer is so aptly advertising, there is no reason why airplanes should be painted to resemble sand barrels when the kind of the air are the most colorful of all creatures.

CONSUMER has not hitherto been given the attention it deserves. An airplane is a vehicle of luxury, inherently smooth in flight, and we believe that the utmost luxury should be provided in aircraft specifications, so that the purchaser will feel he is buying the finest vehicle, land, water, or air, that can be obtained. In all Lockheed,



A Lockheed monoplane equipped with skis for winter operation. This plane, built in Canada, was captured by a commercial airline, Ltd., in Canada during the winter months.

for instance, the entire interior is richly padded carpeted, and upholstered, steel fold for safety and comfort is missing almost hand grip wires are provided for each passenger, sliding windows, controlled weathering, heating, all are built in.

Utility and serviceability of anything, be it an airplane or a machine, are the most important, but since aircraft are considerably more expensive than land vehicles and serviceability is a factor which usually results far below such items in performance and appearance. However, airlines do not buy planes which will not pay profits and possible utility must be built into the plane that would serve airline needs. Utility of aircraft is a lot difficult to define at this state of development but it is probably something of a combination of performance with good load, ability to get the land in and out of the

plane quickly and easily, and manner of disposing the load within the cabin or compartments. With doors, mechanical starters, and ability in inside various types of loads are factors of considerable importance, and must be so regarded.

SERVICEABILITY involves two distinct service during normal operation, and service after a crash. One of the biggest points in favor of Lockheed planes is that during normal usage they require no servicing beyond periodic inspection and painting. This is an important feature of modern aircraft and for quantity sales we must be able to offer planes that will not get out of alignment and which have no hidden parts to rust or deteriorate. Servicing a plane after a crash is a matter which should always rest with the pilot at the factory building the plane. The Lockheed factory has developed a highly satisfactory technique for repairing all minor damages to wing or fuselage. However, although utility and serviceability are of the most fundamental importance, they are not primary sales points, but rather support the hidden value which must be built into any product seeking lasting good will.

Safety is listed as the least important sales point because we believe that it is no longer a logical sales point in connection with selling airplanes. All standard models of planes are now constructed to be of approximately equal safety and it is difficult to build much of a selling argument on the supposition that one plane is safer than another. The better line of attack is to point out that with a good pilot, fair weather, and average terrain, any standard plane can be landed in emergency without a crash or stall. Although not the most important consideration, safety is the most important consideration in manufacture and design of planes and cannot be neglected. Such matters as providing emergency exits, packing chutes, obstructions or eliminating them, running safety belts, etc., are things that cannot be neglected by the manufacturer.

There are, of course, innumerable points of difference as between various planes of the same general type, and perhaps many sales can be made on the basis of such minor talking points, or what we might call "features." But the most important of all sales points is superior speed, without sacrifice of other factors, and that the most important but of them for the manufacturer of aircraft is to build his plane for special services to fit the needs of the many different classes of purchasers within his particular market.

We must not lose sight of the fact that all forms of surface transportation have apparently approached their maximum practical speeds, and numerous costs of operation, leaving the airplane alone on the land. The possibility of great increases in speed of travel along with hope for considerable reduction in operating costs. The plane was not developed primarily for sport or pleasure, but from the very beginning has had increased speed over other forms of transportation as its prime for being. Especially in America speed is the demand of our entire mind in transportation, for time spent traveling is considered time wasted. We cannot hope to predict the speeds to be attained in the future, but of one thing we can be sure: the speeds of the future will be tremendously in excess of those now employed; they will be accomplished through the air, and the planes which deliver the most speed, the others among the other factors, will be the planes which will be most widely sold.

THE VICKERS "Vellore" FREIGHT CARRIER

INTENDED primarily for service as a freight carrier, the "Vellore," recently developed by Vickers, Ltd., Westminster, London, S. W., has proven very successful in the service for which it is needed. Allowing for the weight of plane and fuel for 350 mi. this plane has a payload of 7½ to 8½ per hp. A number of unusual features are incorporated in its design.

The Vellore is a two-bay folding wing biplane built entirely of metal excepting the wings, tail units and rear portion of the fuselage, which are covered with fabric. The power plant is either the Bristol Jupiter IX, which develops 325 hp or the Armstrong Siddeley IX (gas-turbine) engine, which develops 400 hp. The Armstrong Siddeley engine the weight of the plane equals 4,734 lb., the payload 3,625 lb. and the gross weight 9,500 lb. With the Bristol Jupiter the weight empty is 4,750 lb., the payload 3,600 and the gross weight loaded 9,800 lb. The plane has a length of 28 ft. 0 in., a wing span of 76 ft. and a height of 16 ft. 3 in. The width with wings folded is 20 ft. 9 in. The maximum speed of the Armstrong Siddeley powered plane is 150 m.p.h., the initial rate of climb 410 ft. per min. and the absolute ceiling 15,880 ft. The loading speed is 48 m.p.h. With the Bristol Jupiter engine the maximum speed is 114 m.p.h. and the landing speed is also 48 m.p.h. The initial rate of climb is 515 ft. per min. and the absolute ceiling 17,100 ft. In both cases the cruising range is 150 mi.

In this design a low maximum speed was deliberately selected to provide a high payload capacity for operation over difficult country where the airplane would be expected to carry other forms of transportation.

The darkness used in the wing and fuselage is projected against corrosion by the anodic oxidation process after which it is sprayed with a cellulose paint. The wings are of cantilever chord and equal span and the fuselage is attached to the wing offset by struts at the top and bottom. A biplane tail having two balanced elevators and four balanced rudders provides easy and efficient control. The ailerons also are balanced.

The cabin is 12 ft. 9 in. long, 4 ft. 9 in. high and 3 ft. 9 in. wide, giving a capacity of 225 cu ft. A luggage door between the cabin and the rear portion of the fuselage



The Vickers "Vellore" folding wing biplane, designed primarily as a freight carrier.

is provided with blocks and tackle for handling freight. The dimensions of this opening make the loading of lengths of pipe, bar, machine tools or other bulky articles.

The specifications are furnished by the manufacturer:

Length	31 ft. 6 in.
Span	76 ft.
Height	15 ft. 3 in.
Width (wings folded)	20 ft. 9 in.

Performance and weight (Armstrong Siddeley)	
Weight empty	4,734 lb.
Payload	3,625 lb.
Total weight	9,500 lb.
High speed	150 m.p.h.
Landing speed	48 m.p.h.
Initial rate of climb	410 ft. per min.
Absolute ceiling	15,880 ft.
Climb to 4,025 ft.	15 min.
Power loading	30½ lb. per hp.

Performance and weight (Bristol Jupiter)	
Weight empty	4,750 lb.
Payload	3,600 lb.
Total weight	9,500 lb.
High speed	114 m.p.h.
Landing speed	48 m.p.h.
Absolute ceiling	17,100 ft.
Initial rate of climb	515 ft. per min.
Climb to 4,830 ft.	11½ min.
Power loading	39½ lb. per hp.

Heating AND Ventilating FOR AIRPORT BUILDINGS

Article III

Design of Boiler Plant, Smoke Stacks and Selection of Fuel

By E. C. BLACKBURN, JR., M.E.

LIKE ALL the other equipment for a heating system there are many makes of boilers, pumps, etc., on the market. Some of these are more suitable for certain service than others and most of them have their uses and will prove satisfactory if they are properly installed.

As is true of most things that are offered to the public, there are many different grades or qualities available. If the owner happens to be a person who wants the best that can be had, and is willing to spend enough on this phase of the airport, high-class equipment is available. And if he wants the cheapest thing he can get, the equipment is also available.

While it is not essential to use the most expensive equipment to be had, the material which is to be installed must not be of inferior quality or it will be a constant source of worry and expense.

The higher priced pieces of equipment in most cases will have a much longer life than the cheaper ones, due to the fact that they are more carefully designed, the workmanship on them is better and materials used in them is of a higher grade.

For the average airport a well built and solid boiler and water and air equipment that is reasonable in price but still has a background of successful use in many other installations. In other words, it must be an article that is known to be reliable, yet one which may be purchased for a reasonable price.

In designing our boiler plant the first thing we will do is to select the boiler themselves. The type of low pressure heating boilers available

may be divided roughly into two classes, cast-iron, and steel. Both of these types will give satisfaction if they are properly installed, provided that they are large enough to handle the load. Some manufacturers have a tendency to over rate their boilers. This is bad practice and is often the cause of much trouble.

The cast-iron boilers are made up of a number of individual sections fastened together in the way direct radiator sections are fastened together. These sections are cast in such form that when the sections are put together the flanges are lined by a certain number of sections near the front of the boiler. The entire boiler is then covered with insulating material. Steam connections are taken off the top of two or more sections.

The steel boilers, commonly used for this service are of the portable firebox type. They may be either welded or riveted. Several of these boilers that are very similar in construction are available. One boiler of this type is illustrated in Fig. 2, in which the path taken by the hot gases is clearly illustrated.

The number and size of the boilers required for a certain installation depends of course upon the total heating load. It is not practical to install one extremely large boiler even though it may be simple in size, for the reason that in very cold weather this boiler would be operating at a small fraction of its rated capacity with a consequent reduction in efficiency.

The plant should be composed of two or more boilers of a reasonable size. When this is done, in mild weather, instead of operating a very large boiler



Fig. 1

at a low efficiency, it becomes possible to operate one or more moderate size boilers at maximum efficiency.

Therefore, in our boiler plant, we will select two or more boilers. If we use two boilers they must have a total capacity of 80,000 sq. ft. of direct radiation at 40,000 sq. ft. each. These would be too large, so we

may not be obtained from the fuel when used in this way. Smaller stacks are not used merely to carry the smoke from the boilers up to a height where it will not blow in our faces, as some people are not familiar with the subject seem to think. High stacks are used primarily to obtain enough draft to provide sufficient air for complete combustion.

The draft in a smoke stack is created by the height of the stack and the difference in temperature between the air in the stack and the air outside the stack. The hot air in the stack is lighter, due to its higher temperature, than the air outside the stack. Its natural tendency then is to rise or to be goaded up by the heavier air entering the base of the stack via the inlet of the boiler.

There is only one way to avoid these high smoke stacks and that is to provide a system of forced, or induced draft. If this is done the movement of air through the boiler and smoke stack is accomplished by the use of motor driven centrifugal fans, similar to those used for ventilating purposes. In this case the smoke stack can be kept down to a very few feet higher than the surrounding buildings. It would seem that this would be a very important matter and one worthy of serious consideration in an airport installation.

In installing the boilers it is advisable to locate them in such a manner that there will be ample room for access to the sides. There must be sufficient space in the case to permit the reaching to be properly installed, with dampers in the smoke connection to each boiler.

In front there should be a clear space a foot or so longer than the length of the longest boiler in the boiler. This is to permit the clearing of ashes to be carried out with a minimum amount of labor, and also to allow sufficient space for replacing valves in case that should be necessary.

Directly on top of each boiler we will install a stop valve on the steam connection, (see Fig. 3). From these valves the steam is piped, to the steam header.

will try three boilers. If three boilers are to be used they must each have a capacity of 80,000 sq. ft. — 3 = 240,000 sq. ft. This is getting down where reason let us will assume that the ceiling height in the boiler room makes it impossible to install boilers of this size. Therefore, we are forced to occupy more floor space and less height, so we will select four boilers, having a capacity of 20,000 sq. ft. each.

These boilers are located as shown in Fig. 3. The smoke connection in Fig. 3 from each boiler is connected to the breeching, A, Fig. 3. The smoke is conveyed through the breeching to the smoke stack as shown.

While on the subject of smoke let us consider the smoke stack a moment. Smoke stacks and other high objects located on an airport are a constant source of annoyance and danger. Back fuel burned in a boiler requires a certain amount of air for combustion. If this amount of air is not supplied, combustion is not complete and the maximum effi-

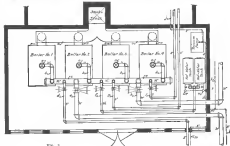


Fig. 3

From the steam header, various connections are taken off as follows:

- d Fig. 3—Steam to building F, Fig. 1
- e Fig. 3—Steam to hangars G, H & I, Fig. 1
- f Fig. 3—Steam to the hot water heaters
- g Fig. 3—Steam to building E, Fig. 1 (The boiler plant building)
- h Fig. 3—Steam to hangars J, K & L, Fig. 1
- i Fig. 3—Steam to building D, Fig. 1

The steam piping is all sized according to the same table we used in sizing the piping in hangar A, Fig. 1, will be as shown in Fig. 3. Valves are installed in each of these lines close to the steam header.

If this arrangement it is possible to control the steam supply to either the North or South group of hangars or any one of the other three buildings.

For example, in mild weather it may not be necessary to supply steam to the hangars and yet it will be a little too cold not to supply steam to the three central buildings. In this case the valves in e and h will be closed, shutting off nearly all of the underground piping.

Under these conditions it will be possible also to shut down one or more boilers. Incidentally, a lag should be



Fig. 4

kept of the operation of the boilers so that an accurate record will be available at all times of the time each boiler has been in operation. This should be so early as possible, the same for each boiler.

A boiler room similar to the one we are designing here is shown in Fig. 4.

The return mains from the various buildings are shown in Fig. 2 and are as follows:

- j Fig. 3—Return from buildings D & E, Fig. 1
- k Fig. 3—Return from hangars G, H & I, Fig. 1
- l Fig. 3—Return from hangars J, K & L, Fig. 1
- m Fig. 3—Return from building F, Fig. 1

These returns from the various buildings are all connected together as shown in Fig. 3. The main return is connected to the vacuum pump as shown.

The vacuum pump is a device, as its name implies, that draws air from the return mains keeping them under a reduced pressure. This has the advantage of causing the steam to circulate more rapidly, makes possible the use of smaller return piping, and also makes it possible to operate the system on lower steam pressures.

One of many types of modern vacuum pumps for use in connection with heating systems is shown in Fig. 5.

The vacuum pump sucks the air drawn from the piping system to the atmosphere and also performs the duty of a boiler feed pump. Thus it also takes the condensed steam, or water, back into the boilers, where it is again evaporated into steam.

The hot water tanks shown in Fig. 3 are regular tanks built for this purpose. They consist of a regular hot-water storage tank in the lower part of which is installed a steam coil for heating the water.

The temperature of the water in the tanks is automatically controlled by a thermostatic device mounted in the water which actuates a valve in the steam supply piping to the steam coil. Thus when the water in the tanks reaches a predetermined temperature, the valve in the steam pipe is automatically closed. When hot water is drawn from some of the hot-water faucets and the temperature of the remaining water in the tank is lowered, the steam valve is automatically opened again.

Another Fig. 3 is installed on the return end of each heating coil, performing the same function as those we installed on the hot water in the hangars. The return from the hot water heaters is connected into the return from the buildings and goes to the vacuum pump also.

The construction of the underground piping to the various buildings is shown in Fig. 1. By running the steam supply and return piping, i Fig. 3, to building D (Fig. 1) through the basement of building E (Fig. 1) we saved quite a bit of underground work.

Just outside the boiler room and at intervals as shown in Fig. 3 we must anchor the steam and return piping. This is usually accomplished by securing a special fitting to the pipe and burying the base of this fitting in a concrete block.

The piping must be exposed and contract as it heats and cools itself, between each two anchors we will install expansion joints in the piping. We will also provide manholes for access to these expansion joints.

The underground piping should be installed in a well-drawn concrete trench in a manner similar to that shown in Fig. 6. The pipes are supported on rollers of some form so that they are free to expand and contract between the points where they are anchored.

The piping should be covered with a good grade of insulating material to reduce as much as possible the loss of heat. This insulation should be protected by a waterproof coating of some good material. Wrapping the insulation with heavy roofing paper, securely fastening it in place with wire, and painting this with one or more coats of hot asphalt paint has been found satisfactory.

Provision should be made to bury the trench in which these return are installed dry. Water around this piping will first destroy the insulation, then absorb heat from the steam as it is surprisingly large amounts. This will be immediately reflected in the cost of operation of the plant. I have known of cases too, where relatively cold water suddenly came in contact with hot steam causing the fittings to fail. Replacing these fittings is an underground job is quite an expensive process too.

Come after there are a number of buildings on an airport that are occupied by firms other than the owners of the airport. In this case steam mains should be installed in the steam distribution system for charging the occupants of these buildings for the steam consumed.

This can be accomplished in several different ways.

The method that is most fair to all parties concerned is to meter the steam used in each building. By this method occupants of the various buildings pay for heat in much the same manner that they pay for electricity gas, etc.

Steam flow meters may be installed in the steam service piping to each individual building, or condensation meters may be installed on the return from each building. In either case the meters may be located in the buildings or they may all be located in the boiler room. It is more desirable to have them located in the boiler room, but this complicates the underground piping system to quite an extent with a consequent increase in cost. This is due to the fact that if the meters are located in the boiler room it becomes necessary to run either an individual steam or return main to each building.

The rate charged for the steam supplied must be based upon the cost of generating the steam. This must include the cost of fuel labor maintenance interest, depreciation, etc.

THERM, MAY BE INSTALLED where individual heating plants in each building may be more advantageous. Usually through the central heating plant is so built, outlined as these articles will be the best. If individual systems are installed in each building they will be most cases be operated by a person who knows nothing about them and uses gas. For this reason they will be discarded and will require a large number of expensive repairs. With the central heating plant all of the principal equipment is located in one place where a competent man can supervise the operation of it and give it the attention it deserves.

The only other means of charging for heat in these buildings based on individual fires is to estimate the amount of heat they will use and include the cost of it in the rental charged. In this case there is no incentive for the occupants of the building to economize because he reasons that he has to pay for it whether he uses it or not.

In this case the airport owner must take into consideration when determining the amount to be included in the rental fee, to protect his own interest. The whole question that becomes related to the occupant of a building who is continuously economical in the use of all season. He is being forced to pay for the steam that the other fellow wastes.

Reasonably accurate condensation meters may be in-

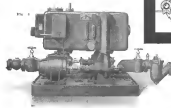


FIG. 1



FIG. 2

has been said on the subject to avoid the present and future builders of airports to the expense of this portion of the work, and to the necessity of having it done by an engineer who is well qualified to do heating and ventilating work and has had experience in this work in the aeronautic field.

stalled that are quite inexpensive. They may be installed in a small out-of-the-way space in each building. Steam flow meters are more accurate but are also more expensive and require more attention.

THE MATTER of fuel is one of great importance and should be given careful consideration. Offhand, I would say that in nearly all cases it will be most desirable to use oil fuel. This will eliminate a large amount of labor and will make installation requiring a minimum of attention.

Then too, when oil is used for fuel a profitable method of disposing of used lubricating oil from the airplane engines is provided. This oil may be strained and poured into the fuel oil tanks. The accumulation of used oil during the summer season when the plant is not in operation will in many cases be sufficient to reduce the fuel bill considerably. In some cases it may be available in sufficient amounts to provide fuel for the entire heating season.

In locations where natural gas is available at a very low price it may be advisable to use gas for fuel and heat some other method of disposing of the used oil.

The use of solid fuels such as coal, wood, etc., should be avoided wherever it is possible to do so. The space occupied by a supply of these fuels is quite large, they are difficult to handle, and make necessary the handling and disposal of ashes.

It is to be hoped that some day it will become possible to locate airports on high well-drained ground. The present tendency seems to be for any city that has enough conveniently located to fill it in and make it so impervious. This makes it necessary to install elaborate drainage systems and causes a great deal of anguish in the part of the engineers who are called upon to design the various phases of the work.

It makes it extremely difficult to obtain adequate heating for the buildings for the hangers and other heavy pieces of apparatus. It makes the installation of the underground drains very difficult, and so away comes another idea that seems very likely to come the boiler room stretch above ground in which case it usually becomes a necessity to build a separate boiler house. However, a separate boiler house in some cases is quite desirable. In conclusion it is in the hope of the writer that enough

Lumber Built

AIRPLANE HANGARS

By N. S. PERKINS, C. E.
Staff Engineer,
National Lumber Manufacturers' Association

*An Advocate of Wooden Hangar Construction
Presents His Opinions on Their
Economic Advantages*

UNTH, there is more certainty along what these engineers will ultimately develop both in plane design and as a public service, there is going to be some emergency as to the proper lines along which airport facilities, in the more detailed arrangements, should be planned.

Meanwhile, as a matter of good business practice, it is well to look upon the airport, whether it be conceptually or privately owned, as a commercial "plant" and to arrange its important decisions along business lines with a view to personal economy and with an allowance for probable changed future requirements. As a business matter, there are those who consider hangar investment at this time the key to successful port, or, let us call it, plan, operation. It is here that money can be spent wisely, or rather it is here that a heavy investment is overhead can be used by the engineer who figures there will be no change in industry or requirements and who encourages the creation of costly, unwieldy structures.

Landfill fields lighting arrangements and such equipment are somewhat rigidly determined by present physical requirements. We practically have no hold them as at present designed for present day operation, even though we know a change may be coming. It is different with the buildings on a port. In these there is room for selection and a choice can be made as to the materials to be used. In making this selection the executive should keep a keen eye to the probability of changed future requirements. He can defend this attitude on a basis of practical economy, and there is no



Interior view of the Standard hangar at Cherry Hill, near Newark, N. J. The roof is of wooden construction, built up of small, well-bolted timbers.

reason why, as an effort to further the economy or make a shrewder he should indulge in needless expenditure of either time or money on dollars.

The first question a businesslike consideration of hangar construction raises is: How far will the investment pay—what will we get for this particular outlay? This raises two first cost, the service the hangar will give in plane handling and plane repairing accommodations, year by year upkeep charges, the heat it will keep in and the cost of the heat in cold climates, as well as the heat it will keep out so that weather can work in some climates, fire resistance, durability, adaptability to economical expansion and remodeling, and finally, salvage value in the event the development of the in-

destroy or public, when complete ultimate total demolition of the particular type of hanger is to be built.

Properly the difference in cost between a reasonable type of construction, which will adequately answer present purposes, and a very expensive hanger of a more permanent type, is so great that the annual savings from the lower interest charges will offset either the upkeep necessities or the provisions of the more costly structure. Take, for example, a 100x100 ft. hanger which can be built for, say \$12,000 if of wood and for \$40,000 if of concrete and steel. It should be explained that these figures will be found to be more practical than arbitrary.

With them, the problem sets itself up in this way:

For the Wood Hanger	
Interest on \$12,000 at 6 per cent	\$720
Maintenance (2 per cent annually)	240
(Based on 125 per cent for framed buildings as average assessment figures used by all authorities)	
Amortization (based on 20-yr life with money at 4 per cent)	400
Total annual charges	\$1,360

For the Concrete-Steel Hanger	
Interest on \$40,000 @ 6 per cent	\$2,400
Maintenance @ 0.6 per cent	400
Amortization (based on 50-yr life and assuming obsolescence factor)	262
	\$3,062

Even if we assume a 15-yr. life for the wood hanger, which is evidently much too low, and assume, also, a four per cent maintenance charge, which is too high, the annual charges on the lumber hanger are only

Interest	\$720
Maintenance	400
Amortization	598



A modern hangar, such as the one used by Pitcairn Aviation of north Carolina Inc., is said to have many advantages.

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These figures give a total of \$1,788 which is still 40 per cent less than the expense each year of the concrete-steel type. It should be remembered also that the lumber building lends itself very readily to the inevitable remodeling or expansion thereby still further reducing year to year cost.

Before jumping to the conclusion that because of these economies the wood hanger is the most desirable, let us consider some other important factors.

What about burning? Most types of hangars can be heated fairly well, the exception being the sheet metal slating construction, which, however, is little used in Northern climates. About the best insulating type is the wood hanger with inside sheathing and with a good quality of building paper between the outside sheathing and siding. Such side walls are very effective heat insulators, greatly reducing the average concrete or brick wall in this respect, according to authoritative engineering data. Heating plant operation and other factors will determine how much of a saving in the winter fuel bill this will make. In the summer the same insulating value keeps the heat out, and in warmer climates has an important bearing on the actual production of air-conditioning to work indoors.

What about fire safety? The prospective hanger builder is often worried about this. Wood is combustible, but the significance of this, especially in comparison with other materials, is often misunderstood. Experience shows that it is usually the contents of the building that make the fire, and fires in all types of hangars have demonstrated that no type of construction is free from damage hazard caused by such contents fires. At an airport conference recently held under the auspices of the Department of Commerce it was stated by an authority on fire prevention that "experience with over 30,000 fires has sufficiently indicated that the character of construction is of negligible consequence in fire control."

Airport managers, no matter what the type of construction, should use that the hanger is kept free from debris and that precautions are taken against explosions

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resulting from sparks. Sheet metal hangars and frame hangers should be kept as free as possible from loose metal tools which should be kept in hand for immediate use. The auto-fire sprayer system is being recommended by the National Society of Fire Underwriters and they are proposing attractively low rates for nearly all types of hangars that have it installed. Some port builders have questioned its need based on experience but tests are to be conducted to demonstrate the sprayer system effectiveness. Meanwhile, with the underwriters offering low rates on sprayer-equipped wood hangars and with experience to demonstrate that contents and care of the premises are more important fire elements than structure type, the executive who builds a wood hanger can count on both low insurance rates and excellent protection on a basis he can defend before stockholders.

It should also be remembered, wood framing has a record for reducing the losses incident to fire, such as wrecked planes, personal injuries and the like. When the framing timbers have charred they serve as a fire retardant, almost invariably containing a plane, whereas other materials are wont to buckle or crumble under the intense heat, especially when cold water is suddenly thrown on to the heated woodwork.

Another factor that should be considered along with the fire hazard is the storm hazard. This has already proved its capacity for doing damage in the airplane



The interior of a wooden structure, showing the best appearance of this type of construction.

hanger field in the recent destruction of a Buffalo hangar. The storms have not wrought a stir here as airports are undoubtedly due to substantial construction plus the fact that storms have not happened to strike some ports where construction is not sound. Experience with buildings similar in design gives ample evidence of what would happen in a hard wind storm to hangars as constructed. The Buffalo experience was an extreme based more on character of construction than on the material used. Presumably in an effort to compensate, the Buffalo hangar was built with an eight inch brick, with a thickness approved by the suggested building code of the Department of Commerce, but only with the under-



An airplane hangar constructed of both wood and steel metal.

standing that it is to be quickly replaced or strengthened. During a heavy rainstorm the air blew through the windows and was compressed against the interior walls and roof. The wood roof had been substantially built, but the wall gave way. One wall was practically demolished and a large hole was torn in another wall.

What about durability? The question of durability involves itself more into a matter of obsolescence. Hangars of all types can be built to stand up for 20, 30, or 40 years. But the problem is rather how long will you want the hangar to stand. It is inconceivable that a hangar built in 1921 (present date) will be as ideal hangar even five years hence. When will the hangar of today become obsolete? When will you want to remodel or remove your hangars?

The same factors that apply to the selection of the site walls of a hangar apply to the selection of the roof. In addition, in constructing the roof, requirements make it necessary to eliminate inside bearing posts or pillars. This is easily accomplished with the wood roof. Also, the Lamella and other principles of tension wood roof construction are now available so that either iron, steel, or roofs from which the steel ribs have been eliminated can be built. In either choice, spans of 120 ft. or greater can be readily spanned without the installation of obstructing pillars. Aerial wood roofs without trans-obstructions are going to provide adequate bearing heights for planes of long perspective measurement—at least for the plane developments that can be projected at this time.

The practicality of these various considerations facing the lumber built hangar is demonstrated in the present trend toward steel construction. At present nearly two-thirds of all hangars in the country are either steel or, more rarely, built of lumber. A bulletin on Airplane Hangar Construction published by the National Lumber Manufacturers' Association, for the prospective hanger builder to have handy, dated in all of late December, '39, prominently listed hangars built of lumber. There have since been several well known additions. This widespread choice is not based on any particular finish. It is a demonstration of the practical wisdom of these changes with the expenditure of monies that go into airport buildings. Original cost economy, prompt remodeling economy, upkeep economy and satisfactory performance have undoubtedly dictated their decision.

THE BUYER'S LOG BOOK



Buhl Air Heater

A NEW type of air heater for engines has been developed by the Buhl Aircraft Company, Maryville, Mo. The use of this device ensures a quick warming up of the engine and, as it is during the warming-up operation that most dirt is encountered, the device is so designed that all air must pass through the cleaner whether being drawn in through a valve or through the cold air opening.

The device consists of a streamline shell which holds the carburetor and within the shell is inclosed an air cleaner of the multiple screen type. The hot air is drawn through the screen on one of the exhaust pipes into the shell, thence through the cleaner and into the carburetor.

The cold air is admitted to the shell through a pair of doors in the front, these doors being controllable from the cockpit. When the doors are fully opened only cold air is admitted to the carburetor due to the fact that the incoming cold air enters under pressure due to the velocity of the plane while the hot air is drawn in over the screen, the door in the section of the carburetor. When the doors are partially opened the cold and hot air



A photograph showing the installation of the Buhl Air Heater in a cockpit engine.

was in the shell, the exact temperature being indicated by a thermometer installed near the cleaner and within the shell. By means of but a single control this temperature may be maintained at any desired degree ranging from the normal air temperature to the full hot condition.

Allen Air Appliance Bulletin

BULLETIN No. A-30 describing in detail the "Triple-A" Centrifugal Air Compressor, has just been issued by the Allen Air Appliance Company, 462 Lexington Ave., New York, N. Y. Several other pneumatic devices are also described in this catalog which is available on request.

Bohnalite "X" Alloy

MANY uses will be found in both the airplane and engine branches of the aeronautical industry for Bohnalite X, a new light alloy wheels is 36 per cent lighter than aluminum and 78 per cent lighter than steel. The alloy is now being produced by the Bohn Aluminum & Brass Corporation of Detroit, Mich.

This new light alloy is being successfully used for castings, forgings and extrusions. Four grades of Bohnalite X are now available and have physical properties as follows:

Bohnalite "X" No. 1 Sand cast—26,000 lb. per sq. in., 15.8 per cent elongation, 44 Brinell, 176 specific gravity.

Bohnalite "X" No. 2 Sand cast—2,800 lb. per sq. in., 14.2 per cent elongation, 57 Brinell, after heat-treat—23-23,000 lb. in., 3-31 per cent elongation, 63 Brinell, 184 specific gravity.

Bohnalite "X" No. 3 Sand cast—28,000 lb. per sq. in., 7 per cent elongation, 50 Brinell, 178 specific gravity, after heat-treat—23-32,000 lb. in., 8-9 per cent elongation, 56 Brinell.

Bohnalite "X" No. 4 Sand cast—21,000 lb. per sq. in., 21 per cent elongation, 45 Brinell, 182 specific gravity, after heat-treat—25,000 lb. in., 6 per cent elongation, 40 Brinell.

Forged Bohnalite X will show tensile strength of 36,000 to 50,000 lb. per sq. in. with 10 to 18 per cent elongation, depending on the particular alloy used and its application.

The physical properties of Bohnalite "X" extruded shapes will vary from 28,000 lb. to 47,000 lb. per sq. in. with an elongation of 10 per cent to 36 per cent, depending on the particular alloy used.

Wrist Chart Board

IN ORDER to meet the demand for a device to steel hold and roll charts and maps printed by the Government or by private concerns in a convenient manner the "Wrist Chart Board" has been developed by J. A. Meyer, 57 Lavette Street, New Rochelle, N. Y. This and several similar devices are now being distributed by aviation supply dealers throughout the country. Various models are supplied to strap to the wrist or knee and are provided with setting for Army strip charts and maps which cover the entire country in numerous routes. Several of these charts in rolls can be placed on the back of the chart board.

These charts can be easily pushed by hand from one end to the other of the board in a short time. Storage space is provided for several state maps which are made in book form. Each map covering a 5,000 sq. mi. area can be placed on the chart board. This is also designed to hold the log book if necessary. The weight of this device is 14 oz.

These chart boards are also being installed in air liners for the convenience of passengers.



The Oldest American Aeronautical Magazine

July 20, 1929



AERONAUTICAL ENGINEERING

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Parents Issued

An Analysis of Airplane Landing Speeds

By ELLIOTT G. REID

(continued from page 190)

IT IS possible that there is not a very widespread realization of the abundance of many of the published performance characteristics of our present commercial airplanes. It appears that the practice of exaggeration is very generally indulged in and there is presented herewith an analysis of airplane landing speeds as an instructive example. It is not desired, however, to create the impression that the criticism is based upon this item alone. It was selected for convenience of dissemination. In lieu of detailed discussion, the statement of two cases which have recently come to the attention of the writer may indicate the territory which is intended. To summarize these examples:

1. A description of a new airplane (not in the table published in AVIATION) indicated the initial rate of climb with full load. Calculation demonstrated that the rate at which the weight of the machine would be elevated, in a vacuum, by the application of the rated power of the engine through a mechanism having a mechanical efficiency of 65 per cent (an optimistic estimate for climb work) was slightly less than the advertised rate of climb.

2. Two new airplanes, A and B, were announced by their manufacturers at about the same time. According to the published figures, B's top speed was about 30 m.p.h. greater than A's. With both now in service, it appears that the data in one or the other foot and that A is about 10 m.p.h. faster. As the writer has been shown excellent reasons for securing the performance test of A, B's advertising doesn't look so good.

Let us now examine the landing speed situation in some detail. It is best illustrated graphically. Fig. 1 was generated from the data given in the table "Manufacturers' Specifications on American Commercial Airplanes and Seaplanes as Compiled in AVIATION," published in the issue of AVIATION dated May 18, 1939. The ordinates of this chart are landing speed in miles per hour ("Performance with full load at sea level as applied by manufacturers") and wing loading is 30 sq ft ("gross gross weight loaded"/"wing area"). The points designated by single circles represent the airplanes listed in the table. In the case of lighter weights stated as "A to B m.p.h.," the mean value $(A+B)/2$ has been used. The points identified by double circles are added for comparison; they represent the nine military airplanes used for the tests described in N.A.C.A. Technical Report No. 246, "Landing and Take-off Characteristics of a Number of Service Airplanes," probably the most accurate study of the load ever recorded.

Any unbiased reader will admit that Fig. 1 resembles the familiar chart of "The Hazards in Free." There appears to be some relationship among the points for

the military airplanes but the whole chart is speckled with points representing commercial machines. While all our textbooks state that a large wing loading is invariably accompanied by a high landing speed, one can difficulty in correlating this rule with Fig. 1 in which, for example, airplanes with wing loadings ranging from 5.85 to 16.80 lb. per sq ft. are seen to be credited with the same landing speed—46 m.p.h.

Most textbooks, the older ones at least, also tell us that the landing speed of an airplane may be calculated by subdivisions of the maximum lift coefficient for the wings in the usual formula relating this coefficient with lift wing area, speed and air density. It will be demonstrated below that this procedure is not justifiable and that an airplane lands at a speed corresponding to a lift coefficient smaller than the maximum. Common sense would dictate this conclusion since it is generally realized that the controllability of an airplane on the verge of stalling would be inadequate for landing. The values of the lift coefficients at landing speed are, however, well worth some study. For the airplanes listed in the table, they have been computed in accordance with the equation

$$C_L = \frac{2W}{\rho V^2 S} = q^2$$

whereas

$$\begin{aligned} C_L &= \text{Absolute lift coefficient} \\ W &= \text{Weight of airplane (lb.)} \\ \rho &= \text{Mass density of air (slugs/cu ft.)} \\ S &= \text{Wing area (sq ft.)} \\ V &= \text{Landing speed (ft./sec.)} \end{aligned}$$

$$q = \frac{\rho V^2}{2} = \text{dynamic pressure (lb./sq ft.)}$$

The results are plotted as the ordinates of Fig. 2, the absolute wing loadings. As in Fig. 1, double circles for the tested military airplanes have been added for comparison. The fact that the largest lift coefficient established by these carefully made experiments is only 1.31, constitutes a convincing proof that airplanes do not attain their maximum lift coefficients at landing. The abundance of the majority of the landing speeds is now clearly apparent in the values of the lift coefficients. These lift coefficients not only exceed the true experimental, determined values but also surpass the most recent lift coefficients of any loaded wing, in fact some of the data corroborates the highest values obtained by Handley Page and Lockheed in their experiments with deeply slotted wings.

The problem now confronting us is to establish a dividing line between fact and fiction. In view of the

excellent confirmation by British flight tests of model tests made in the N.A.C.A. variable density tunnel, a would seem fair to base the decision upon airfoil tests made in this tunnel. The maximum lift coefficients of several frequently used airfoils as determined by tests at 20 ft. atmospheric pressure, are listed below.

M—4	0.94	U.S.A. 35 A	1.21
M—6	1.22	U.S.A. 35 B	1.27
M—12	1.29	R.A.F. 15	1.21
U.S.A. 35	1.39	Goett 387	1.33
U.S.A. 27	1.39	Clark Y	1.38

(Taken from S. I. C. I. Technical Note No. 30)

These figures indicate, in a very remarkable way, that any sort of normal lines will develop at full scale Reynolds number, a lift coefficient greater than 1.4. This conclusion is also borne out by flight tests. The largest flight test C_L value of which I am first made is 1.46, and the method of test errors seems to favor the result of the accuracy. (A single exception is found in the case of the R.A.F. 19 airfoil. Variable density tunnel tests at full scale Reynolds number gave $C_{L_{max}}$ at 1.65 for the airfoil and 1.42 for an airplane model with wings of this section; the latter value has been corrected to flight. No American airplane has wings as highly cambered as is the R.A.F. 19.)

Let us now counter Fig. 1 again. A curve of wing loading vs. landing speed for $C_L = 1.4$ appears there, parallel to B and displaced therefrom by increments of 5 m.p.h. are four curves which serve to indicate the maximum probable errors in the advertised landing speeds. It is believed that the errors are, in most cases, slightly larger than those indicated by the chart. Eighty-seven airplanes are listed in the table but only 43, these, are not considered as the data are incomplete. Of the remaining thirty-three machines seven are not seen to

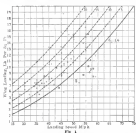


Fig. 1

emerge—i.e., the lift coefficients at landing speed are less than 1.4. Seventy-one airplanes are credited with supposedly low landing speeds, nine of these appear to involve errors of less than 5 m.p.h., thirty-one lie between 5 and 10 m.p.h., twenty-five fall between 10 and 15 m.p.h. and ten cases show the error exceeds 15 m.p.h.

It is anticipated that explanations involving "high lift

wings," "ground effect," "skilled piloting," etc., may be offered in defense of some of these figures. The subtle features of these considerations can be treated rather briefly.

Differences between wing profiles are of no importance in regards landing speeds unless (as is very rarely the case) the angle of attack in the landing condition ap-

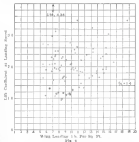


Fig. 2

proaches closely, or exceeds that corresponding to maximum lift. In other words if, for the R.A.F. 15 wings of a conventional type of airplane, there be substituted a wing having the same plan form and arrangement, but of Göttinger 387 profile, and the latter be so rigged that zero lift will occur with the fuselage in the same attitude with respect to the relative wind as in the original condition then the landing speeds may be expected to be equal. It is assumed, of course, that the weight of the airplane remains unchanged. It is only the conceptual and rather apprehensible, case mentioned above would it be beneficial to substitute a wing having a large maximum lift coefficient for a profile having a smaller one.

There is nothing particularly mysterious about the effect of proximity to the ground upon wing characteristics. It is simply a reduction of the reduced angle of attack with a corresponding increase of the slope of the lift curve. Unfortunately for the use of this subterfuge as an explanation of the statement of very high lift coefficients on landing, the lift curve slope does not increase indefinitely as the height/span ratio is reduced but, on the contrary, approaches a discretized asymptotic value which is only a little greater than the slopes of the lift curves for high aspect ratio airfoils. Studied from another point of view, the greatest possible effect is complete deceleration of the induced angle of attack which is a small part of the geometric angle of attack. At a given angle of attack, then, the greatest possible increase of the lift coefficient obtainable by approaching the ground is relatively small.

While it is undoubtedly true that a skilled pilot can, under favorable conditions, land an airplane at a speed lower than its normal landing speed, this has no bearing on the case in hand. It is casually assumed that the

advertised landing speed corresponds to a straightforward three-point landing and not a "vacuole".

The underlying cause of the present state of other confusion with respect to landing speeds are not readily seen. It appears probable, however, that the difficulty of obtaining reliable experimental information at the airport, without resorting to elaborate and expensive methods of testing, is one of the chief factors. Air-speed meter readings are not entirely reliable unless a hovering Pitot tube is used and even then installation errors due to position may become appreciably large. During the course of a motor car or other vehicle in search for truthfulness, simplicity and accuracy is undoubtedly needed.

In conclusion, it has been shown that a large proportion of the published landing speeds of American commercial airplanes is unnecessarily erroneous. It is the writer's belief that a similar, although possibly less exaggerated, condition is to be found among the other principal performance characteristics. If aerodynamic engineering is to be kept from degenerating into meaningless words and figures, the time for unified and drastic action is ripe. It is suggested that airplane manufacturers, as a group, take such action as will prove necessary to provide themselves with a source of authentic performance data such as is now available to engine builders in the results of the Department of Commerce Type Tests.

Analysis of the Wing and Other Indeterminate Structures

By JEAN FRADIES and ARMAND THIENLOT

Fokker Aircraft Corp.

Part II

TECHNICAL REVIEWS

N.A.C.A. Technical Report No. 515, Aerodynamic Characteristics of Airfoils—VI, continuation of Reports Nos. 92, 124, 132, 244 and 265.

This collection of data on airfoils has been made from the published reports of a number of the leading aerodynamic laboratories of this country and Europe. The previous collection of airfoil sections numbered 1 to 259 and Charts 7 to 29 may be found in N.A.C.A. Reports Nos. 93, 124, 182, 244 and 286. The information which was originally expressed according to the different standards at the several laboratories is here presented in a uniform series of charts and tables suitable for the use of design engineers and for purposes of general reference.

The absolute system of coefficients has been used since it is thought by the National Advisory Committee for Aeronautics that this system is the one most suited for international use and yet it is one from which a desired transformation can be easily made. For this purpose a set of transformation constants is given.

Each airfoil section is given a reference number, and the test data are presented in the form of curves from which the coefficients can be read with sufficient accuracy for designing purposes. The dimensions of the profile of each section are given in various stations along the chord in per cent of the chord length, the latter also serving as the datum line.

The N.A.C.A. Technical Report No. 509, Pressure Distributions over the Horizontal and Vertical Tail Surfaces of the P-51 Pursuit Airplane in Pullout Maneuver, by R. P. Shobe.

This investigation of the pressure distribution on the tail surfaces of a pursuit airplane in violent maneuvers was conducted by the National Advisory Committee for Aeronautics at the request of the Navy Bureau of Aeronautics for the purpose of determining the maximum loads likely to be encountered on these surfaces in flight. The information is a part of that needed for a revision of existing loading specifications to bring these into closer agreement with actual flight conditions. A standard P-51 airplane was used and the pressure distribution over the right horizontal and complete vertical tail surfaces was recorded throughout violent maneuvers. The results show that the existing loading specifications do not conform satisfactorily to the loads actually existing in critical conditions, and in some cases were exceeded by the loads obtained.

An acceleration of 10.5 g was recorded in one maneuver in which the pilot suffered severely.

American Society for Testing Materials paper, Fatigue Resistance of Some Aluminum Alloys, by J. B. Johnson and T. T. Obry.

This paper is presented as additional data on the endurance properties of aluminum alloys. Several investigators have presented such data, but a noticeable discrepancy exists in the results as related. The endurance of fatigue tests has been based on the basis of about 800,000,000 cycles. The results reported in this paper indicate that 500,000,000 cycles are sufficient to determine the endurance limit. An endurance limit at 300,000,000 cycles is satisfactory for most practical purposes, but with modern aerial equipment a propeller may be subjected to over one billion alternations of stress in a year's service.

S.A.E. Semi-Axial Meeting paper, Volatility Data on Natural Gasoline and Blended Fuels, by Oscar C. Brinkman.

The evaporation of the equilibrium air distribution with the Bureau of Standards to more volatile fuels requiring measurements at temperatures considerably below 0 deg. C. (32 deg. F.) has shown that the general relations obtained from the previous work are equally applicable to natural gasoline and to straight run aviation fuels and to natural gasoline motor fuel blends.

N.A.C.A. Technical Memorandum No. 515, Materials and Methods of Construction in Light Structures, by Adolf Rohrbach, from the Year Book of the Wissenschaftliche Gesellschaft für Luftfahrt.

N.A.C.A. Technical Memorandum No. 516, Combined Stacking of 2-Cycle Engines, by Hans Lotz, from Zeitschrift des Vereins deutscher Ingenieure.

N.A.C.A. Technical Memorandum No. 517, Investigation of the Effects of the Passage on the Wing of a Low Wing Monoplane, by H. Hottel, from Luftfahrtforschung.

N.A.C.A. Technical Memorandum No. 518, Investigation of Characteristics of Combustion, by J. Sander, from Zeitschrift des Vereins deutscher Ingenieure.

N.A.C.A. Technical Memorandum No. 519, Force Measurements on Airplanes, by F. Seiwald, from Zeitschrift für Flugtechnik und Motorluftschiffahrt.

N.A.C.A. Technical Memorandum No. 520, Theoretical Rigidity of Composite Wings, with Constant Spar and Rib Sections, by Giorgio Gherlini, from Luftfahrtforschung.

IN THIS first paper we have shown that the elementary methods based upon the rules of statics are insufficient for solving most of the problems which are brought daily to the attention of the aeronautical engineer. Hence the need and importance of more exact methods.

Besides a rigorous investigation based on advanced methods of structural analysis, coordinated with exact aerodynamic data, by giving an accurate knowledge of the true margin of safety, is an important factor in the development of new designs and leads to a lighter and more efficient structure.

Structurally indeterminate cases are so frequent in airplane design, that they seem to be, not the exception, but the rule. And these indeterminate systems can be solved only by the advanced methods based on the elastic properties of the structure.

The load factors imposed on airplane structures being comparatively small, it is very important that the engineer should know with exactitude the nature and distribution of the stresses.

As they are presented to the aeronautical engineer, are not only complicated because of the natural complexity of airplane structures, but also because of the lack of precision regarding the external forces.

For instance, it is just as hard to compute the stresses in a wing structure due to the torsional moment as to determine this moment with accuracy.

But we have seen that with the aid of the Theorems of an airfoil section, and the Elastic Center of a wing sec-

tion it is comparatively simple to solve such a problem.

The advances based on the elastic properties of the structure are sometimes very rapid and sometimes very complicated. But in the latter case, it is often possible to find a particular solution that simplifies the problem—like the focus and the elastic center of a wing section permitting the comparison of the true loads as the span, the true torsional movement and the loads in the compressive members of a wing section. Nevertheless particular solutions of a general problem of solutions for indeterminate structures are always based on the method of elasticity.

A Wing Structure Forms a System that is not Statistically Determined.

There are three cases of static indeterminacy:

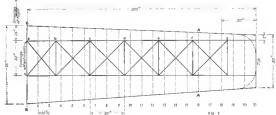
I—External, the existence of too great a number of supports to determine the reactions by the rules of statics (for a multi-span wing or a wing without spar the reactions on the fuselage structure are not statically determinate).

II—Internal, the presence of redundant member (such as compression member or wing covering).

III—External, the shape of the body being such that an elementary distribution of the stresses is impossible (complex metal structures, wing covering, etc.).

Therefore any kind of wing structure has several indeterminate elements.

Often the engineer makes an arbitrary simplification in order to transform the structure into a statically determined system—but practice shows that the error



involved is often of the same magnitude as the load on the members and therefore this simplification must be justified.

We will give several examples of practical analyses of wing structures considered as indeterminate systems.

Example 1: Analysis of a wing structure of the conventional type.

We will analyze a cantilever fabric covered wing built up of two wooden spars connected by a drag strut, as shown in Fig. 1.

The structure is indeterminate because it is impossible to obtain by means of statics regardless of the elastic properties of the structure:

- I.—The true external loads on the spars
- II.—The true stresses in the spars
- III.—The loads in the compression members

I.—The two spars being connected by an inter-spar structure, that causes them to deflect together, are not independent of each other. According to the location of the center of pressure and to the relative inertia of the spars one of them will have a tendency to deflect more than the other. But greater deflection however will be partially or totally prevented by the compression members which will tend to equalize the deflections on both spars, thus adding to the torsional rigidity in preventing to a certain extent, the wing section from shearing to shape—since the load taken by each spar is proportional to its deflection this load is not determined.

II.—The true stresses in each spar cannot be determined if the modulus of the drag members are not known—and generally there is too great a number of them.

The equations of equilibrium or any graphical distribution of the forces are insufficient to compute the true loading moments of the spars.

III.—The loads in the compression members are functions of the elasticity of the spars and therefore cannot be determined by means of statics alone.

The general method based upon the statistics in the case of a wing structure, often leads to very complicated calculations.

The following method based on the consideration of the elastic center is considerably shorter and easier. Only its degree of accuracy, though for those that give by the elementary conventional method is slightly less than the degree of accuracy of the general method.

Our purpose is to show the insufficiency of the elementary method but not at all to deny its use, for instance to give an idea of the stresses. In this particular case we will first determine the section modulus of the spars by means of the common approximate method and then find the true loads. In fact, most methods based on the elasticity are "cut and try" methods, in which a pre-determination of the size of the member is made before the exact computations are carried out.

For the sake of shortening the method, we will adopt the following program:

I.—Pre-determination of the loads on the spars and of all their action moduli by the conventional approximate method, in such a manner that the margins of safety are equal to zero.

II.—Computation of the true loads on the spars showing that the true margin of safety is not equal to zero but is positive in certain part of the wing and negative in another part of the wing.

III.—Determination of the loads in the compression members.

IV.—Calculation of the spars by the general process method outlined above.

Pre-determination of the loads on the spars and section moduli.

The analysis is made in accordance with the U. S. Department of Commerce, Regulations.

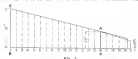
We will assume the thickness ratio at the root to be equal to 30 per cent and the thickness ratio at the tip to be equal to 10 per cent.

Useful Area

$$\frac{75 + 50}{2} \times 200 = 12,500 \text{ sq. in.} = 85.8 \text{ sq. ft.}$$

Effective Area

In determining the effective area and equivalent wing, sections 1, 4, 8, 12, 16 sq. ft. considered. At section 16,



the chord is approximately equal to the distance in the wing tip. The tip length is therefore assumed to be 50 in. (chord at the section 16) and the decrease of the semispan for tip loss is then 5 in.

The chord length of the equivalent wing at each of the above sections are calculated and listed below in Table I.

Section	1	4	8	12	16
Distance from root tip	160	140	120	100	80
Thickness of spar	11	11	11	11	11
Distance from spar to spar	15	15	15	15	15
Thickness 1/8 in. each	15	15	15	15	15
Chord of equivalent wing	15	47.5	58	61	58

Area of the equivalent wing: 9,253 sq. in. = 64.53 sq. ft. (See Fig. 2.)

Let us suppose:

Weight of the plane = 1,760 lb.

Weight of the wing = 320 lb.

Load factor = 7 (for the high angle of attack condition)

Total load = 10,220 lb.

Total load on one wing 10,220

Load per sq. ft. = 29.18 lb./sq. ft.

Load per sq. in. = $K = 549$ lb.

Shear & Moments on the Front Spar Right Angle of Attack

The distance of the front spar from the leading edge is given by the equation:

$$37 + \frac{46 - 37}{200} x = 37 + 0.045 x$$

x being the distance of the section considered from the tip of the wing. The distance from the center of

pressure located at 30 per cent of the chord the leading edge:

$$30(30 + \frac{75 - 30}{200} x) = 15 + 0.075 x$$

The distance from the rear spar to the center of pressure:

$$37 + 0.05 x = 35 = 0.075 x = 22 + 0.075 x$$

Shearing force on the front spar:

From tip to A we have (y being the ordinate of the trailing edge of the equivalent wing),

$$y = 14.72 + \frac{33 - 14.72}{200} x$$

$$y = 14.72 + 365 x$$

The distance from rear spar to center of pressure:

$$5(30 + \frac{75 - 30}{200} x) = 25 + 9625 x$$

$$25 + 9625 x = (15 + 0.075 x) = 20 + 0.075 x$$

$$\text{Load factor} = 0.55$$

$$\text{Load per sq. in.} = K = 350$$

$$\text{Load on the rear spar}$$

$$\text{The ordinate of the equivalent wing is:}$$

$$y = (14.72 + 0.365 x)$$

being A , and k the root loading:

Referring to Fig. 3 we have:

$$y = \frac{d}{32} K \frac{d}{32} = \text{Increase of load on front spar}$$

Shear at A :

$$S_x = K \int_0^x y \frac{d}{32} dx$$

When $K = 549$ lb. per sq. in.

and root $d = 22 + 0.075 x$

$$S_x = K \int_0^x (14.72 + 365 x) \frac{22 + 0.075 x}{32} dx$$

$$S_x = \left[0.000408 \frac{x^3}{3} + 3.39 \frac{x^2}{2} + 5.53 x \right]_0^x$$

$$S_x = 453.2 x$$

Between A and B the chord of the equivalent wing is:

$$y = 19 + \frac{75 - 33}{180} x = 19 + 280 x$$

The shear at any point between A and B is given by the following equation:

$$S = \int_0^x (19 + 280 x) \frac{22 + 0.075 x}{32} dx + S_A$$

$$S = 0.00036 \frac{x^3}{3} + 108 \frac{x^2}{2} + 7.16 x + C$$

The constant C is determined by condition that when $x = 50$, $S = S_1$, $C = -41.29$

$$S_B = \left[0.00036 \frac{x^3}{3} + 108 \frac{x^2}{2} \right. \\ \left. + 7.16 x - 41.29 + 453.2 \right]_{50}^{100} + 453.2$$

$$S_B = 3046.7 \text{ lb.}$$

The bending moment is obtained as the integral of the shear:

$$M_x = \int_0^x \left[0.000408 \frac{x^3}{3} + 3.39 \frac{x^2}{2} + 5.53 x \right] dx$$

$$= 9835 \text{ in. lb.}$$

Between A and B , the moment is:

$$M_x = \int_0^x \left[0.00036 \frac{x^3}{3} + 108 \frac{x^2}{2} + 7.16 x - 41.29 \right] dx$$

$$M_x = 274588 + M_A$$

$$= 284423 \text{ in. lb.}$$

Shear & Moment on the Rear Spar (Low Angle of Attack Condition)

Distance from Front Spar to leading edge:

$$\frac{16 - 5}{200} x = 5 + 0.050 x$$

Distance from leading edge to center of pressure (at 50 per cent of chord):

$$5(30 + \frac{75 - 30}{200} x) = 25 + 9625 x$$

Distance from front spar to center of pressure:

$$25 + 9625 x = (15 + 0.075 x) = 20 + 0.075 x$$

Load factor = 0.55

Load per sq. in. = $K = 350$

Load on the rear spar

The ordinate of the equivalent wing is:

$$y = (14.72 + 0.365 x)$$

Shear at A :

$$S = \frac{K}{32} \int_0^x (14.72 + 0.365 x) (20 + 0.075 x) dx$$

$$S = \int_0^x (0.00067 x^3 + 0.0889 x + 3.27) dx$$

$$S = 271.29 \text{ lb.}$$

Between A and B we have:

$$S_1 = \frac{K}{32} \int_0^x (19 + 0.280 x) (20 + 0.075 x) dx$$

$$\text{Total Shear} = S + S_1 = 2,387.2 \text{ lb.}$$

The bending moment is obtained as the integral of the shear:

$$M_x = \int_0^x \left[0.00067 \frac{x^3}{3} + 0.0889 \frac{x^2}{2} + 3.27 x \right] dx$$

$$M_x = 5872 \text{ in. lb.}$$

Between A and B the moment is given by the equation:

$$\int_0^x \left[0.00055 \frac{x^3}{3} + 0.0629 \frac{x^2}{2} + 4.23 x + C \right] dx$$

C being determined so that for $x = 50$ the shear is equal to 271.29

We have:

$$296 + \frac{C}{3} = 271.29$$

$$C = -25$$

$$M_B = \int_0^{100} \left[0.00055 \frac{x^3}{3} + 0.0629 \frac{x^2}{2} + 4.23 x - 25 \right] dx$$

$$M_B = 19339 \text{ in. lb.}$$

$$207 = M_A + M_B = 175231 \text{ in. lb.}$$

Shear and Bending Moment on the front spar is low angle of attack condition

$$S_x = \frac{K}{32} \int_0^x (14.72 + 0.365 x) (12 - 0.0175 x) dx$$

$$= 142.36 \text{ lb.}$$

$$S_p = \frac{K}{32} \int_0^{100} (10 + 0.280x) (12 - 0.0175x) dx$$

$$= 867 \text{ lb.}$$

$$S_r = 1,019 \text{ lb.}$$

$$I_1 = \frac{K}{32} \int_0^{100} (-0.0064x^3 + 4.825x^2 + 170.6x) dx$$

$$= 3,307 \text{ in.}^4$$

$$M_1 = \frac{K}{32} \int_0^{100} (-0.0049x^4 + 3.60x^3 + 228x^2) dx$$

The constant of integration is determined so that $M_1 = 3,567 \text{ in.}$
 $M_2 = 82,272 \text{ in.}$
 $M_3 = 85,632 \text{ in.}$

Determination of Section Moduli of the Spars
 The lighter spar is designed by the condition

$$\frac{M}{I/Y} = (\text{constant})$$

But, in the case of a wooden spar with unequal flange depths, we have:

$$\frac{M}{(I/Y)_c} = (E\epsilon_c) \text{ is compression} = C_c$$

$$\frac{M}{(I/Y)_t} = (E\epsilon_t) \text{ is tension} = C_t$$

hence:

$$\frac{y_c}{y_t} = \frac{C_c}{C_t} \quad (1)$$

$$\text{and } y_c + y_t = k \quad (2)$$

Where k is the mean spar height

$$y_c = \frac{kC_c}{C_c + C_t}$$

y_c and y_t are determined by equation (1) and (2). We will assume $C_c = 3,500 \text{ lb./sq. in.}$ and $C_t = 8,000 \text{ lb./sq. in.}$, so that, with a normal width, the thickness of the lower flange is not less than half the thickness of the upper flange.

Front Spar in High Angle of Attack Condition

The moments between the tip and A are obtained by the equation determined above:

$$M_1 = 0.000046 \frac{r^4}{12} + 0.139 \frac{r^3}{2} + 5.55 \frac{r^2}{2}$$

At any point between A and B the moment is given by the expression:

$$M_2 = 0.000336 \frac{r^4}{12} + 0.138 \frac{r^3}{2} + 7.16 \frac{r^2}{2} - 41.29x + C$$

When $x = 50$, $M_2 = M_1 = 9,835 \text{ in.}$ B and hence $C = 681$

Front Spar— M A A
 Determination of the Moment of Inertia

Section	20	17	14	11	8	5	2
x	10	40	70	100	130	160	190
b	4.5	6	7.5	9	10.5	12	13.5
h	1.84	2.45	3.06	3.67	4.28	4.89	5.5
M	298	5893	20966	50651	96217	161415	249445
$(I/Y)_c$	.354	1.071	3.299	9.239	17.494	29.34	45.25
$(I/Y)_t$	.969	2.63	12.05	33.70	74.86	143.47	249.43
Corrected I	5	8					

The moments of inertia of sections No. 20 and No. 17 are respectively increased to 5 in.⁴ and 8 in.⁴

The same calculation is made for the rear spar in the following table:

Rear Spar in Low Angle of Attack Condition							
Section	20	17	14	11	8	5	2
x	10	40	70	100	130	160	190
b	2.75	3.78	4.88	6	7.25	8.5	10.4
h	1.12	1.53	1.99	2.46	2.92	3.46	4.07
M	193.2	3631	13177	30551	58365	98598	153342
$(I/Y)_c$	0.033	.66	2.295	5.510	10.161	17.92	27.88
$(I/Y)_t$	.037	1	4.77	13.34	30	62	113
Corrected I	3.2						

Computation of the True Loads on the Spars

We will consider both spars in the low angle of attack condition.

The computations will be based on the following theories:

The deflection of a point C of the neutral axis of a straight beam with one end fixed and the other free is equal, with the opposite sign to the area of the moments with respect to this point of successive vertical

up-loads, $\frac{M}{EI} dx$, (the absolute value of M being considered), acting as each element dx of the portion of the neutral axis between C and the fixed end.

Therefore, if the deflection due to the shearing forces is neglected, the formula giving the deflection of a point located at a distance a from the tip of the wing is:

$$\lambda = - \int_a^x \frac{M(x-a)}{EI} dx$$

Where x is the distance from the tip to the root (See Fig. 4.) By differentiating the above formula twice,



Fig. 4

with respect to x , we find the differential equation of the neutral axis:

$$\frac{d^2\lambda}{dx^2} = - \frac{M}{EI}$$

Since the moment of inertia is variable we will divide the spar into six sections and assume the moment of inertia to be constant and equal to the mean moment for each section. These sections are limited by the compression members.

In the first paper we have defined the "Elastic Center" as a point such that a load acting at this point creates equal deflections of the two spars.

This point is located at distances from the spars inversely proportional to their moments of inertia

(Therefore, the distance from the rear spar to the elastic

center is) $a = \frac{I_1}{I_1 + I_2}$. D , (D being the distance between the spars).
 If the total load were acting at the elastic center, the deflection of a point located at a distance a from the wing tip would be:

$$\lambda = \int_a^x \frac{(M_1 + M_2)(x-a)}{E(I_1 + I_2)} dx$$

Where M_1 is the moment of the front spar

M_2 the moment of the rear spar.

The load in a compression member is proportional to



Fig. 5

the difference between deflection of the total wing and that of the spar alone.

The effect of the presence of the compression member is to nullify this difference of deflection Q (See Fig. 5). For the rear spar at the first compression member, we have:

$$\lambda_R = \int_a^x \frac{M_2(x-a)}{EI_2} dx \quad (1)$$

Where M_2 is the bending moment of the rear spar



Fig. 6

at the first compression member and I_2 the mean moment of inertia between the wing root and the first compression member (see Fig. 6).

We have:

$$Q = \int_a^x \frac{(M_1 + M_2)(x-a)}{E(I_1 + I_2)} dx - \int_a^x \frac{M_2(x-a)}{EI_2} dx$$

or

$$Q = \int_a^x \frac{M_1(x-a)}{E(I_1 + I_2)} dx - \int_a^x \frac{M_2(x-a)}{EI_2} dx$$

and

$$Q = \int_a^x \frac{(x-a)}{E} \left[\frac{M_1}{I_1 + I_2} - \frac{M_2}{I_2} \right] dx$$

But, since the compression member nullifies the difference of deflection, we can write

$$Q = 0 \quad (2)$$

The moments of a compression member on each spar are equal. Therefore, we have one unknown for each compression member. The moment at any point is a function of these unknown reactions and we can solve the problem by writing equation (2) for each compression member.



Fig. 7

position number. In the present case we have to solve the following system of six equations with six unknowns:

$$\begin{cases} Q_1 = \int_a^x q_1(R_1) dx = 0 \\ Q_2 = \int_a^x q_2(R_2) dx = 0 \\ Q_3 = \int_a^x q_3(R_3) dx = 0 \\ Q_4 = \int_a^x q_4(R_4) dx = 0 \\ Q_5 = \int_a^x q_5(R_5) dx = 0 \\ Q_6 = \int_a^x q_6(R_6) dx = 0 \end{cases}$$

Where $R_1, R_2, R_3, R_4, R_5, R_6$ are the unknown reactions of the compression members on the spars.

These reactions are assumed to be directed upward for the front spar and downward for the rear spar.

The bending moment of a spar between two compression members i and j (Fig. 7) is given by the equation:

$$M = \sum_{k=i}^j R_k d + (x-a) \sum_{k=i}^j R_k + M_1$$

Where $\sum_{k=i}^j R_k d$ is the moment of the reactions of the compression members about the compression member i .

The compression members about the compression member i .

$$(x-a) \sum_{k=i}^j R_k \text{ is the moment of the sum of the}$$

reactions of the compression members, supposed to be acting at the compression member i , with respect to the compression member i .

M_1 is the moment due to the airload about the section considered.

Table 3—Front Spar
Front part of the beam

x	$0.00014 \frac{x^2}{12 \cdot 10^7}$	$0.016 \frac{x^2}{36 \cdot 10^7}$	$2 \cdot 10^{-6} \frac{x^2}{5 \cdot 10^7}$	$-1.1 \frac{x^2}{5 \cdot 10^7}$	Result
0	0	0	0	0	0
100	1.4	1.6	0.04	-1.1	1.9
200	5.6	6.4	0.16	-4.4	7.7
300	12.6	14.4	0.36	-9.9	17.2
400	22.4	25.6	0.64	-17.6	29.8
500	35.0	40.0	1.00	-27.5	44.5
600	50.4	57.6	1.44	-39.6	61.2
700	68.6	78.4	1.96	-53.9	79.1
800	89.6	102.4	2.56	-70.4	98.7
900	113.4	129.6	3.24	-89.1	120.6
1000	140.0	160.0	4.00	-110.0	144.0
$a=1$	-36.154	124.12	39950	100.5	14400 $\frac{1}{10^7}$
$b=1$	10270	151.88	127146	8770	23432 $\frac{1}{10^7}$
$\frac{1}{2}a+\frac{1}{2}b$	3259	49.75	34449	2750	11170 $\frac{1}{10^7}$
$\frac{1}{3}a+\frac{2}{3}b$	1410	27.54	35700	4250	3610 $\frac{1}{10^7}$
$\frac{2}{3}a+\frac{1}{3}b$	262.14	6.9	15020	2680	16070 $\frac{1}{10^7}$
$\frac{1}{6}a+\frac{5}{6}b$	19.15	0.79	302.8	126.1	1261 $\frac{1}{10^7}$

Table 4—Front Spar
Front part of the beam

x	$0.00014 \frac{x^2}{12 \cdot 10^7}$	$0.016 \frac{x^2}{36 \cdot 10^7}$	$2 \cdot 10^{-6} \frac{x^2}{5 \cdot 10^7}$	$-1.1 \frac{x^2}{5 \cdot 10^7}$	Result $\times 10^5$
0	0	0	0	0	0
100	1.4	1.6	0.04	-1.1	1.9
200	5.6	6.4	0.16	-4.4	7.7
300	12.6	14.4	0.36	-9.9	17.2
400	22.4	25.6	0.64	-17.6	29.8
500	35.0	40.0	1.00	-27.5	44.5
600	50.4	57.6	1.44	-39.6	61.2
700	68.6	78.4	1.96	-53.9	79.1
800	89.6	102.4	2.56	-70.4	98.7
900	113.4	129.6	3.24	-89.1	120.6
1000	140.0	160.0	4.00	-110.0	144.0
$a=1$	-36.154	124.12	39950	100.5	14400 $\frac{1}{10^7}$
$b=1$	10270	151.88	127146	8770	23432 $\frac{1}{10^7}$
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$\frac{1}{6}a+\frac{5}{6}b$	19.15	0.79	302.8	126.1	1261 $\frac{1}{10^7}$

TABLE 5			TABLE 6		
M	M_0	$M_0 - M$	M	M_0	$M_0 - M$
Front Part of the Beam	Front Part of the Beam	Moment of the Beam	Front Part of the Beam	Front Part of the Beam	Moment of the Beam
0	0	0	0	0	0
100	1.4	1.6	100	1.4	1.6
200	5.6	6.4	200	5.6	6.4
300	12.6	14.4	300	12.6	14.4
400	22.4	25.6	400	22.4	25.6
500	35.0	40.0	500	35.0	40.0
600	50.4	57.6	600	50.4	57.6
700	68.6	78.4	700	68.6	78.4
800	89.6	102.4	800	89.6	102.4
900	113.4	129.6	900	113.4	129.6
1000	140.0	160.0	1000	140.0	160.0

Table 7—Front Spar
Front part of the beam

x	$0.00014 \frac{x^2}{12 \cdot 10^7}$	$0.016 \frac{x^2}{36 \cdot 10^7}$	$2 \cdot 10^{-6} \frac{x^2}{5 \cdot 10^7}$	$-1.1 \frac{x^2}{5 \cdot 10^7}$	Result
0	0	0	0	0	0
100	1.4	1.6	0.04	-1.1	1.9
200	5.6	6.4	0.16	-4.4	7.7
300	12.6	14.4	0.36	-9.9	17.2
400	22.4	25.6	0.64	-17.6	29.8
500	35.0	40.0	1.00	-27.5	44.5
600	50.4	57.6	1.44	-39.6	61.2
700	68.6	78.4	1.96	-53.9	79.1
800	89.6	102.4	2.56	-70.4	98.7
900	113.4	129.6	3.24	-89.1	120.6
1000	140.0	160.0	4.00	-110.0	144.0
$a=1$	-36.154	124.12	39950	100.5	14400 $\frac{1}{10^7}$
$b=1$	10270	151.88	127146	8770	23432 $\frac{1}{10^7}$
$\frac{1}{2}a+\frac{1}{2}b$	3259	49.75	34449	2750	11170 $\frac{1}{10^7}$
$\frac{1}{3}a+\frac{2}{3}b$	1410	27.54	35700	4250	3610 $\frac{1}{10^7}$
$\frac{2}{3}a+\frac{1}{3}b$	262.14	6.9	15020	2680	16070 $\frac{1}{10^7}$
$\frac{1}{6}a+\frac{5}{6}b$	19.15	0.79	302.8	126.1	1261 $\frac{1}{10^7}$

We have:

$$Q = \int_a^b (1-v) \left[\frac{M_x}{I_x} - \frac{M_y}{I_y} \right] dx = 0$$

or

$$Q = \int_a^b (x-v) \frac{M_x}{I_x} dx - \int_a^b (x-v) \frac{M_y}{I_y} dx = 0$$

Since we have assumed I to be constant between two compression members, we can write:

$$Q = \int_a^b (1-v) \frac{M_x}{I_x} dx + \int_a^b (x-v) \frac{M_y}{I_y} dx + \int_a^b (x-v) \frac{M_x}{I_x} dx + \int_a^b (x-v) \frac{M_y}{I_y} dx$$

$$Q = \int_a^b (1-v) \left[\frac{M_x}{I_x} + (x-v) \frac{M_y}{I_y} + M_0 \right] dx - \int_a^b (x-v) \left[\frac{M_x}{I_x} + (x-v) \frac{M_y}{I_y} + M_0 \right] dx$$

The quantities M_x and M_y have the opposite sign on the front spar and on the rear spar.

The values of the moments are given for each station for the front spar in Tables I and II. Table I gives

the first part of the integral, that is $\int_a^b x M_x dx$ and Table II gives the value of $\int_a^b M_x dx$. The coefficient of M_y is given by the value of $\int_a^b (x-v) M_y dx$, which is given in Table III.

The same values are computed for the rear spar in Tables IV, V, and VI.

The coefficient of M_x is given by the expression:

$$\int_a^b (1-v) dx$$

For the first section we have:

$$\int_a^b (x-175) dx = 313 \text{ in.}$$

It is obvious that, the stations being equally spaced,

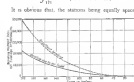


Fig. 3—Front spar bending moment, low angle of attack

this coefficient is constant and equal to:

$$\int_a^b (x-145) dx = 430$$

The coefficient of M_x is given by the expression:

$$\int_a^b (x-v) dx$$

For the first section we have:

$$\int_a^b (x-175) dx = 460$$

As for the coefficient of M_y , this coefficient is constant for the other sections and equal to:

$$\int_a^b (x-145) dx = 937.5$$

Table VII gives the values of the coefficients of M_x and M_y divided by the moment of inertia. (The first line refers to the front spar and the second line to the rear spar.) The third line shows the difference or the result of equation (5) for each section.In Table VIII expressions M_x and M_y are determined. The first line lists the values of M_x drawn from M_x and the second line the same values drawn from M_y .The sum of these first two lines, which is given in the third line of the table, is the coefficient of M_x . And so forth for each section.

Therefore the coefficients of the first equation are given by the third line of Table VIII.

In order to determine the coefficients of the second equation the third line of Section 5 is added to the third line of Section 2. The third line of Section 8 is added to the third line of Section 5 to determine the coefficients of the third equation, etc.

Reactions of the compression members

Substituting Equation (6) from the fifth we have:

$$396 R_0 = 470 \text{ lb.}, R_0 = 117 \text{ lb.}$$

and by successive elimination in the other equations:

$$R_1 = 131 \text{ lb.}$$

$$R_2 = 170 \text{ lb.}$$

$$R_3 = 210 \text{ lb.}$$

$$R_4 = 260 \text{ lb.}$$

$$R_5 = 340 \text{ lb.}$$

The bending moment of the front spar and of the rear spar are respectively shown in Fig. 3 and Fig. 2. The plain lines show the moments calculated by means of the simplified common method and the dotted lines show the corrected moments.

It can be seen that the influence of the compression members on the distribution of the loads in the wing

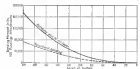


Fig. 4—Rear spar bending moment, low angle of attack

structure is very important and should not be neglected if some accuracy is desired. Nevertheless this influence is particularly great in the above example because the moment of inertia of the rear spar is nearly half of that of the front spar. Besides the difference between the results given by the two methods would have been smaller if the deformation of the compression members and the moments at the joints of struts to the spars had been taken into account.

This was neglected because of the great difference

The third of three articles will appear in an early issue

TABLE VII

Second part of the diagram

λ	$\frac{1}{\lambda^2}$ in 10^6	$\frac{1}{\lambda}$ in 10^3	$\frac{1}{\lambda^2}$ in 10^6	$\frac{1}{\lambda}$ in 10^3	$\frac{1}{\lambda^2}$ in 10^6	$\frac{1}{\lambda}$ in 10^3
100	1.00	0.01	1.00	0.01	1.00	0.01
101	0.99	0.01	0.99	0.01	0.99	0.01
102	0.98	0.01	0.98	0.01	0.98	0.01
103	0.97	0.01	0.97	0.01	0.97	0.01
104	0.96	0.01	0.96	0.01	0.96	0.01
105	0.95	0.01	0.95	0.01	0.95	0.01
106	0.94	0.01	0.94	0.01	0.94	0.01
107	0.93	0.01	0.93	0.01	0.93	0.01
108	0.92	0.01	0.92	0.01	0.92	0.01
109	0.91	0.01	0.91	0.01	0.91	0.01
110	0.90	0.01	0.90	0.01	0.90	0.01

TABLE VIII

Section	J	W	W	Comment
7	199.41	14.05	14.05	$W = \frac{1}{2} (W_1 + W_2) + \frac{1}{2} (W_3 + W_4) + \frac{1}{2} (W_5 + W_6)$
8	199.41	14.05	14.05	$W = \frac{1}{2} (W_1 + W_2) + \frac{1}{2} (W_3 + W_4) + \frac{1}{2} (W_5 + W_6)$
9	199.41	14.05	14.05	$W = \frac{1}{2} (W_1 + W_2) + \frac{1}{2} (W_3 + W_4) + \frac{1}{2} (W_5 + W_6)$
10	199.41	14.05	14.05	$W = \frac{1}{2} (W_1 + W_2) + \frac{1}{2} (W_3 + W_4) + \frac{1}{2} (W_5 + W_6)$
11	199.41	14.05	14.05	$W = \frac{1}{2} (W_1 + W_2) + \frac{1}{2} (W_3 + W_4) + \frac{1}{2} (W_5 + W_6)$
12	199.41	14.05	14.05	$W = \frac{1}{2} (W_1 + W_2) + \frac{1}{2} (W_3 + W_4) + \frac{1}{2} (W_5 + W_6)$
13	199.41	14.05	14.05	$W = \frac{1}{2} (W_1 + W_2) + \frac{1}{2} (W_3 + W_4) + \frac{1}{2} (W_5 + W_6)$
14	199.41	14.05	14.05	$W = \frac{1}{2} (W_1 + W_2) + \frac{1}{2} (W_3 + W_4) + \frac{1}{2} (W_5 + W_6)$
15	199.41	14.05	14.05	$W = \frac{1}{2} (W_1 + W_2) + \frac{1}{2} (W_3 + W_4) + \frac{1}{2} (W_5 + W_6)$

TABLE IX

Section	B	R_1	R_2	R_3	R_4	R_5	Comment
2	12.5	11.5	11.5	11.5	11.5	11.5	$W = 10$ feet separation
3	12.5	11.5	11.5	11.5	11.5	11.5	$W = 10$ feet separation
4	12.5	11.5	11.5	11.5	11.5	11.5	$W = 10$ feet separation
5	12.5	11.5	11.5	11.5	11.5	11.5	$W = 10$ feet separation
6	12.5	11.5	11.5	11.5	11.5	11.5	$W = 10$ feet separation
7	12.5	11.5	11.5	11.5	11.5	11.5	$W = 10$ feet separation
8	12.5	11.5	11.5	11.5	11.5	11.5	$W = 10$ feet separation
9	12.5	11.5	11.5	11.5	11.5	11.5	$W = 10$ feet separation
10	12.5	11.5	11.5	11.5	11.5	11.5	$W = 10$ feet separation
11	12.5	11.5	11.5	11.5	11.5	11.5	$W = 10$ feet separation
12	12.5	11.5	11.5	11.5	11.5	11.5	$W = 10$ feet separation
13	12.5	11.5	11.5	11.5	11.5	11.5	$W = 10$ feet separation
14	12.5	11.5	11.5	11.5	11.5	11.5	$W = 10$ feet separation
15	12.5	11.5	11.5	11.5	11.5	11.5	$W = 10$ feet separation

of the moment of inertia of the spars and the compression members. The above calculations show that, the rear spar for instance, though computed for a margin of safety equal to zero in low angle of attack, in fact has a positive margin of safety. But if similar calculations were carried out for the high angle of attack condition it is likely that the influence of the front-spar structure would be of such a magnitude that the margin of safety of the rear spar for this condition would be negative.

British Methods of Steel Aircraft Construction

By W. H. SAYERS

London & Paul Ltd.

AT THE present time stress is made of the leading aircraft manufacturers of Great Britain regularly employ steel for the main structural members of wings in their military aircraft, as against only two who have adapted themselves for this purpose.

The first airplane with steel wings based on the use of corrugated strip for wing spars was the M.R.1 produced by the Bristol Aeroplane Co. Ltd. (then known as The British and Colonial Aeroplane Co. Ltd.) in 1918. To this firm belongs the credit of having so early realized the possibilities of this type of construction. This machine was in a whole a Bristol design, but the detail design and construction of the wings was entrusted to the Steel Wing Co. Ltd., who may fairly claim to have been the earliest practitioners of this art.

As early as 1912 one J. J. Morrow proposed and patented the use of thin strips of metal in corrugated form for the purpose of constructing airplane spars and other components, and a year or so later the construction of a machine embodying his scheme was attempted in England. Mr Morrow was not successful in his efforts, but in 1915, D. J. Mooney purchased the Morrow patent, and formed the organization afterwards known as the Steel Wing Co. Ltd., which has recently been absorbed by the Gloster Aircraft Co. Ltd. of Crowthorne. To this organization a large share is the credit for the progress of the technique of steel construction must be credited.

Other pioneers of this art are Armstrong Whitworth Aircraft Ltd. of Coventry, and Boulton and Paul Ltd. of Norwich, both of whom have been engaged on this class of construction for ten years. For some six or seven years the Bristol Aeroplane Co. Ltd. has also applied its energies to the development of steel strip construction, and for a shorter period, The H. G. Hawker

Co. Ltd. of Kingston-on-Thames has taken an active part in the same work.

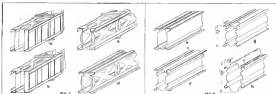
This list is not to be taken as exhaustive. Others have played a part, but it is believed that it is fair to ascribe to these firms the bulk of the technical progress made up to date.

There is description of the methods peculiar to these firms will suffice to give a fairly complete account of the practical applications of the principles which were outlined in the earlier article of this series.

The Steel Wing Co. (Gloster Aircraft Co. Ltd.)

As the first firm to produce wings of the type now being discussed the work of this firm is of special interest from the historical point of view and it is therefore proposed to review in some detail the process of evolution through which steel wing-spars of these designs have passed. The earliest spars by this firm were built-up girders of the type shown in Figs. 7 (a, b, c, d). These consisted originally of four trough-section beams connected both vertically and horizontally by some form of bracing strip.

At (a) the vertical bracing consists of two vertically corrugated strips which meet on, and are riveted to, the two edges of each trough assembly. The horizontal bracing consists of two stamped strips forming a lattice stiffened at intervals by transverse struts. As (b) the four beams have been provided with beaded edges in order still further to stiffen them. This type of spar was not very efficient as a large amount of material was employed in the webs where it was ineffective in resisting and the loads. At (c) is shown an improvement consisting of the formation of the web members in one with channels which form part of the flanges of the complete spar while the webs have been lightened by stamp-



service types for the Royal Air Force shall be of metal construction.

The earliest steel spars made by this firm were built-up of channel sections stiffened by corrugations, as shown in Fig. 16. This type was superseded by a type developed by Major H. N. Whyte who is the firm's technical authority on steel construction. One of these spars used on the first Bristol machine which was previously mentioned is shown in Fig. 17.

Owing to the difficulty of attaching fittings to this single welded arrangement the production Siskens were provided with spars of the type shown in Fig. 18. Fig. 19 shows an end fitting for this type of spar, from which it will be seen that internal reinforcement by a



Fig. 16

special forging supplemented by external plates is employed. Fig. 20 shows a fitting for cableways and drag bracing on a similar spar which employs a somewhat similar internal forging through which the forging bolts for the fitting pass.

The difficulties of attaching fittings to the single web type of spar were later overcome by the use of what are called "pig rivets," which can be clenched into the walls of a closed tube from the outside, and this type of spar has recently been revived.

The pig rivet is hollow with a forward head on one end. A piece of rod with a conical end two-thirds its length from the hole is threaded through the rivet so that the conical head is at the end opposite to the head. Holes

and "tail" as the tail is called, are then pushed through the rivet hole, and the tail is withdrawn, causing the end of the rivet inside to expand and forcing the body of the rivet tight into the wall into which it is inserted. Figs. 20, 21, 22 show the modern single web type of spar in a variety of depths. It will be noted that whereas in the earliest spars the sections used consisted of a series of curves of fairly large radii, the more recent types use a series of flats connected by angles or ridges. This form, it is claimed, simplifies tool-making and permits of more accurate formation of the desired sections. Also it is said that the stiffening effect of the relatively sharp bends is greater than that of the larger radii and results in a stronger spar. The processes of flat faces also provide good bearings for fittings that are to be riveted on.

The tubular booms of the spars illustrated are built up from three separate members with projecting lips on which are drawn coping strips of a hollow form, riveted through the lips. These strips provide ridges of great strength and give a concentration of metal where it is effective in giving the spar resistance to both lateral and vertical bending.

The corrugated webs used with this type of spar have proved exceptionally satisfactory. They owe their effectiveness in large part to the torsional rigidity of the tubular booms to which they are attached.

Fig. 23 shows another type of single-web spar in which the boom is drawn from a single strip instead of being built up from several strips. This type is used chiefly for very light spars. This figure also shows how local reinforcement for the attachment of fittings is provided by inner tubes in the booms, fastened to pop rivets, and by side plates.

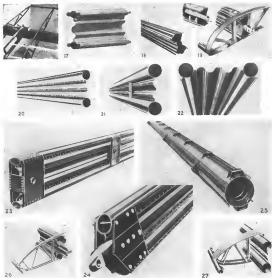
Fig. 24 shows an end fitting on one of the heavier type spars with a similar one of inner tubes and side plates.

Fig. 25 shows a tubular spar used for ailerons, etc. This is built up just as are the spar booms, from a series of segments, and is provided with internal stiffening diaphragms. This construction gives great torsional rigidity at a much lower weight than can be attained with a solid drawn tube.

Ribs made by this firm are of rolled strip section in a somewhat wider steel than is used for spars, and of thicknesses usually 0.008 in. and 0.010 in. Various sections have been used, including tubes with inwardly bent



Fig. 18



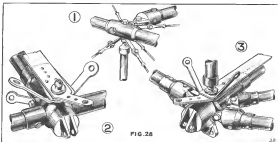
ped edges, square or rectangular tubes, and channel sections. In all such sections it is important that the edges should be stiffened by flanging or bending. Examples of such ribs are shown in Figs. 26 and 27 which also show the method of attaching the ribs to the spars.

A process known as "draw-rolling" is employed for the formation of many of the sections made by this firm. In this, forming takes place on a draw-bench lat, instead of the usual fixed bed, rollers are used. It is much easier to produce straight members by drawing than by the usual rolling process, and this combined method combines the advantage with the reduced expenditure of power and higher speed of forming that is possible with normal rolling methods.

Spar and similar sections are formed from strip steel in the fully annealed condition and are thereafter hardened by a very ingenious process in which the formed strip is heated to the required temperature by passing through it

a heavy electrical current. The strip is held under tension during the process which ensures straightness. The steel used is of the air-hardening type and thus no special quenching arrangement is necessary.

Finishing frames are made from solid-drawn tubular members with insulated fittings of a type such as those shown in Fig. 28. Although the more usual type of welded fastening joint is now permitted by British regulations, this type of machine fitting is considered by many designers to have many advantages. In particular, clones of steel which cannot safely be welded can be used, and, although the machined fitting is more costly when made in comparatively small numbers, it is felt that in the event of production on a really large scale, the fact that fittings can be made on automatic or semi-automatic machinery and assembled by men or unskilled labor gives this type a distinct advantage over the welded joint. This advantage might become particularly important in



the event of a shortage of supplies of steel suitable for welding, which might occur in war time. It is of course true that the supplies of mild steel will be available whenever steel of any kind can be found and that such material is particularly suitable for welding. But the advantages of being able to use material of higher quality are too great to be forgotten merely because suitable steel for welding of such quality might be difficult to obtain.

All components of the complete steel framing are carefully cleaned by the use of scratch brushes to remove scale, and are thereafter stove enameled. This has been found to afford satisfactory protection against corrosion.

under all service conditions. As this mechanism is based on the construction used by the Royal Air Force of all steel machines of this make for some six years it can safely be assumed that, despite the apparent susceptibility of members of a thickness of a few thousandths of an inch to damage by rust the steel machinery of this type does not suffer in this respect under any conditions likely to be encountered in the normal way. It should be recorded that the all steel Armstrong Whitworth "Sisnie" has been in service in Egypt, Iraq, and India, as well as in England and has proved satisfactory in all these climates.

(The concluding article of this series will appear in the August 1936 issue.)

PATENTS ISSUED

Patent No. 1,716,630—Device for Launching and Landing Airplanes From and Upon Suspended Panniers *Lawrence S. Sperry Farmingdale N. Y.*, assignor, by mesne assignments, to *Lawrence Sperry Aircraft Co., Inc., Farmingdale, L. I., N. Y.* Twenty-five claims.

Patent No. 1718566—*Arroyo Landing Gear*. Knott Hewitt Inc., Garden City, N. Y., assignor to Curtiss Aeroplane & Motor Co. Inc. Powerless aircraft.

Patent No. 1,719,798—Airtight. Charles J. McCar, My. Flushing, and Michael Walter, New York, N. Y., assignors to Chester M. Fought, Great Neck, N. Y. (See above).

Parent No. 1719798—Aeroplane and Landing Chariot
Thereafter: Michael Walter, New York, N. Y., assignor
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Patent No. 1,719,799.—*Aircraft*. Michael Watter, New York, N. Y., assignor to Chester M. Fought, Great Neck, N. Y. Thirteen claims.

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Gender: Male; Ideal Strength: 1000 N; Age: 14 years

Patrol No. 1718390—Hjaleg Mochsen. Larus I. Tómas. Malmby. Mous. Esch. claus.

Patent No. 1,718,415—Asplene Fawcette, Joseph L. Cato, Buffalo, N. Y., assignors to G. Burt & Bro., Inc. Buffalo, N. Y. *Stictica clausa*.

Patent No. 1,718,577—Aircraft Device—Harold F. Phipps, Bryn Athyn, Pa. See class.

Patent No. 1728417—Aeroplane. Charles J. Wagner, Chicago, Ill.

Patent No. 1,718,703—Control Mechanism for Aero-planes. Harvey M. Salisbury, Walnut Grove, and Arthur E. Miller, Sacramento, Calif. See claims.

Patent No. 1,718,834—Airless. Clarence G. Pratt.
Architects, Calif. Our claim.

Patent No. 1,718,932—Aeroplane. Frank Brown, Berkeley, Calif. Mar. 24/29.

Patent No. 1,719,298—Griffin Paul E. H. Griffin

MANUFACTURERS' SPECIFICATIONS ON AMERICAN COMMER

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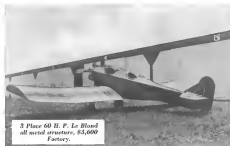
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Double integrated switch shorts
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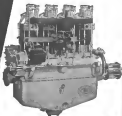
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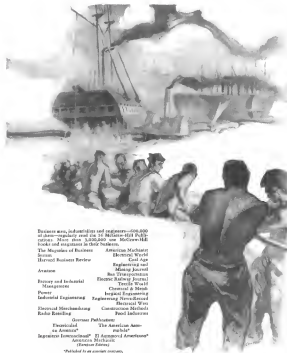
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